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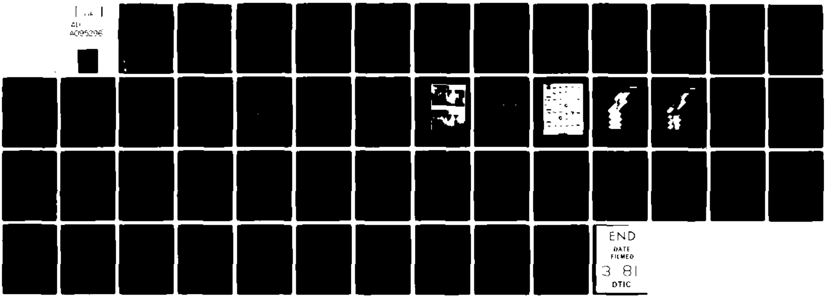

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AIR FORCE GEOPHYSICS LABORATORY
AIR FORCE SYSTEMS COMMAND
UNITED STATES AIR FORCE
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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This report describes the support services supplied by KEO Consultants to the operation, and improvement of the All-Sky-Imaging-Photometer on the NKC-135 Airborne Ionospheric Observatory. Data analysis and results are also described. A new digitizing system constructed to facilitate analysis of video images is described, together with the associated computer software.

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1. Introduction:

In 1976-77, KEO Consultants designed and constructed an all-sky imaging photometer (ASIP) for the Air Force Geophysics Lab (Contract F19628-76-C-0168). The system was installed on the NKC135 Airborne Ionospheric Observatory (AIO) in Jan., 1977, and has become a prime research instrument on the observatory. The ASIP images a 160° field of view through four selectable 30Å filters, and records images of intensity $\gtrsim$ 20R on both film and TV video tape. Research has been carried out in the dayside and nightside auroral regions, and in equatorial airglow regions. A full description of the instrument, and some applications, may be found in AFGL publication #TR-77-0155.

The present contract, F19628-77-C-0097 (April 1977 - Sept. 1980) is essentially a follow on to the first contract, and involved the following tasks:

1. Improvements, modifications, and repairs to the ASIP as deemed necessary by consultation between AFGL and KEO.
2. KEO participation in planning of arctic and equatorial experiments, and analysis of data from these experiments.
3. Design, construction and testing of a Digitization System to facilitate computer analysis of video tapes, and provide necessary software.

2. Summary of Progress by Line Item

2.1 Line Item 0001AA - Investigate the characteristics of auroral particle precipitation into the upper atmosphere using measurements from the all sky imaging photometer, all sky camera and meridian scanning photometer on the AFGL Airborne Ionospheric Observatory. Specific airborne missions to be investigated will be selected by AFGL scientists.

The contractor participated in planning discusssions for a number of research flights during the contract period. These included:

1. Coordinated flights at South Pole conjugate point, June, 1977.
2. Auroral zone and dayside auroral flights Dec., 1977 - Jan., 1978, and Jan., 1979.
3. Equatorial airglow flights, March, 1978.

Data was supplied to AFGL from South Pole and Canadian photometer installations to aid in coordinated data analysis.

4. Contractor also participated in discussions concerning AFGL support for the new AF over-the-horizon radar system, located in Maine.

Data from the flights has been analyzed by AFGL scientists, and led to numerous reports, talks at scientific meetings, and the following published papers:

Weber, E.J., J. Buchau, R.H. Eather and S.B. Mende, North-south aligned equatorial airglow depletions, J. Geophys. Res., 83, 712, 1978.

Weber, E.J., J. Buchau, and J.G. Moore, Airborne studies of equatorial F layer ionospheric irregularities, J. Geophys. Res., 85, Oct., 1980.

Weber, E.J., and J. Buchau, Polar cap F-layer auroras, submitted to Geophysical Research Letters, 1980.

2.2 Line Item 0001AB - Investigate the latitude/local time dependence of particle precipitation in the vicinity of the auroral oval using AFGL Airborne Ionospheric Observatory measurements as well as simultaneous ground based imaging photometer measurements made at high latitude ground stations operated by the Contractor. The schedule for the coordinated measurement program will be planned by AFGL scientists. The Contractor will arrange to operate his equipment on approximately 7 nights during the winter 1977-78 to perform this investigation.

The contractor (under a separate NSF grant) operated a meridian photometer chain in central Canada during the 1977-78 winter. The data from the coordinated experiments with the Airborne Ionospheric Observatory were analyzed by the contractor and AFGL scientists, and are described in the Report attached as Appendix 1.

2.3 Line Item 0001AC - Modify the T.V. optical system to allow 90 degree field of view measurements in addition to the present 160° field of view. Completed by the contractor in June, 1977.

2.4 Line Item 0001AD - Modify the T.V. Camera remote high voltage power supply to allow presettable and calibrated high voltages to be applied to the T.V. camera. Completed by the contractor in August, 1977.

2.5 Line Item 0001AE - Modify video signal processing to provide a means to display the video waveform to insure that it is within prescribed operating limits and to assist in remote high voltage adjustment. Completed by the contractor in June, 1977.

2.6 Line Item 0001AF - Investigate techniques to decode, playback and rephotograph selected frames recorded on video tape by the AFGL All sky Photometer. Investigate techniques to reorient and display All Sky Photometer images to more accurately locate the true spatial position of auroral phenomena.

This item was the subject of numerous meetings between the contractor and AFGL scientists. KEO recommendations were prepared into a report submitted to AFGL in June, 1978 (see Report KEO-05). This led to further discussions with AFGL, resulting in a second report submitted by KEO in Oct., 1979 (see Report KEO-06). More discussions with AFGL led to their request for a detailed proposal, including estimated costs, which was prepared and submitted in March, 1979. AFGL issued a purchase request for the proposed digitization system, leading to KEO's formal proposal of September, 1979. This proposal was approved, and additional funding added to the contract to finance design and construction. The contract expiration date was extended to June 30, 1980.

2.7 Line Item 0001AG - Design and construct a special purpose hardware system, to digitize the video taped auroral images from the all sky imaging photometer. The system must be capable of reading and decoding encoded video data (EVD) which contains parameters such as Julian Date, time, filter number, exposure duration and high voltage setting. The system must decode the EVD contained on each image for comparison with preselected values. The system should automatically select the video field with the best replay signal to noise ratio, and reject repeat frames on the video tape. The system should then digitize a full TV field containing 256 x 256 elements with 6 bit resolution per element. The final digital tape will be formatted to contain the EVD followed by the digitized TV video field.

Completed by the contractor Sept. 10, 1980. (A no cost time extension of the contract period was necessary because of unexpected problems in construction, and problems with an AFGL supplied digital tape recorder). The digitizing system is described in detail in Appendix 2.

2.8 Line Item 0001AH - Computer programs will be written in FORTRAN Language to analyze the digitized auroral images. The programs will be capable of transforming the auroral image from all sky lens geometry of the all sky imaging photometer to geographic or corrected geomagnetic coordinates, using appropriate emission height assumption. The program will be run on the AFGL CDC 6600 computer and should be fully documented. The presentation format will be contour plots or grey scale plots of auroral intensity. Also, the programs should have the ability to add or subtract two fields. Computer software in accordance with Attachment No. 2, Contract Data Requirements List, DD Form 1423, dated 79 Sep 11. This software was completed Sept. 30, 1980, and delivered to AFGL Oct. 8, 1980. A brief description is given in Appendix 3. The programs:

a) Transformation of all-sky image geometry to geographic and geomagnetic coordinates.

b) Programs developed to use the AFGL CDC 6600 gray scale plotter and contour plotters, with appropriate axis labelling. Considerable difficulty was encountered with the gray-scale plotter, and KEO resolution of these problems will assist other users at AFGL.

2.9 Line Item 0001AJ - Process meridian scanning photometer data from three ground stations operated by the Contractor in Canada. Data will be processed for the periods when the AFGL AIO was performing airborne auroral experiments in January, 1979. Approximately five days will be selected by the Contract Monitor. The processed data will consist of latitude-time-intensity plots of auroral emissions at 4278A, 4861A, 5577A and 6300A and plots of derived quantities including 6300/4278 ratios, average energy and energy flux for precipitating electrons.

This task was completed in August, 1980, and is described in the report attached as Appendix 1.

2.10 Line Item 0002 - Data is required and shall be prepared in accordance with Contract Data Requirements List DD Forms 1423 dated 79SEP11 attached hereto and made a part hereof.

Quarterly Status Reports KEO-01 through KEO-11 were prepared and approved July 15, 1977, through Feb. 15, 1980. No report was prepared June 30, 1980, and work through the period Feb.-August, 1980 was covered in Quarterly Status Report KEO-12.

Final Report submitted October 15, 1980.

3. Additional Tasks Completed

When this contract was written, it was recognized that many problems that might arise with the ASIP system were unpredictable, and that required modifications/improvements would depend on experience with the instrument and new experiments that developed. Consequently, AFGL and KEO recognized the need for KEO to maintain an open and responsive attitude to the program, and respond as positively as possible to situations and requirements as they developed. The following lists some of the tasks completed by KEO that were not specifically spelled out as contract line items.

3.1 Measurement of vignetting characteristics of optical system. The 3:1 vignetting (center→edge) could be corrected by a variable density filter in the field plane (Report KEO-02), but at a sacrifice in sensitivity.

3.2 Complete ASIP calibration, including voltage linearity, exposure linearity, absolute calibration, wavelength sensitivity, and vignetting. A 16-page report was submitted (Report KEO-02). The text of this report with representative figures, is included as Appendix 4.

3.3 Design and construction of two devices to supply edge of field markers for the ASIP images (Reports KEO-2, KEO-3, KEO-09).

3.4 Complete revision and simplification of KEOGRAM computer programs used by AFGL, including corrections for narrow auroral features (Report KEO-4).

3.5 A study of DMSP satellite images and their calibration was completed and published in the Journal of Geophysical Research (attached as Appendix 5). Although not funded by this contract, the work was of direct interest to AFCL scientists (Report KEO-06).

3.6 Facilitation of repair of ASIP HV supply, and Video Recorders, as necessary during contract period.

3.7 Provided new filters for the ASIP as requested by AFGL.

3.8 The Principal Investigator gave two seminars at AFGL during this contract period.

3.9 Absolute calibration of AFGL supplied Variable Intensity Light Source.

3.10 Provision of a Colorado Video Frame Grabber, later integrated into the digitizing system. The cost of this item was offset by less expenditure than expected on consultants.

4. Conclusions

KEO Consultants have provided a large variety of support services associated with the ASIP over the $3\frac{1}{2}$ - year period of this contract. Their services have included repairs, improvements, new designs, new data analysis equipment, data analysis and interpretation. We have developed a flexible relationship with the Ionospheric Dynamics Branch at AFGL that allows quick and optional response to AFGL requests and requirements. To this end, KEO employs part-time consultants in the fields of physics, electronic design and fabrication, mathematical analysis and computer programming. This allows us maximum flexibility at minimum cost and overhead.

The ASIP has become one of the prime instruments on the Airborne Ionospheric Observatory and has resulted in new discoveries in auroral physics, equatorial depletion regions, and polar cap emissions. All the discoveries impact directly on communications and radar systems, of direct operational interest to the Air Force.

This research work is planned to continue over the next three years, during which KEO will continue to provide support services of the type described in this Final Report. This work will be carried out under the recently awarded Contract F19628-80-C-0153.

Appendix A

Co-ordinated Dayside-Nightside Auroral Experiment

During January, 1979, a co-ordinated experiment was conducted to try to determine the relationship between dayside (midday) and nightside (midnight) auroral movements during substorms. It is known from previous work that the aurora near midnight intensifies and expands rapidly poleward at the onset of a substorm, whereas the midday aurora moves equatorward in response to substorms (Eather et al., 1979, and references therein). But co-ordinated data are required to answer such questions as: (JGR South Pole Paper)

1. What is the timing delay, if any, between dayside and nightside auroral movements?
2. What is the relative magnitude of movements?
3. How does dayside and nightside recovery compare?

At issue in the answers to such questions are the relative importance to auroral dynamics of dayside merging, nightside reconnection, and substorm current systems.

To conduct the required co-ordinated experiment, simultaneous auroral data are required under midday and midnight regions, with both regions in darkness. No two ground stations can satisfy this condition, so the experiment was planned as a co-ordination between the AFGL Airborne Ionospheric Observatory and a meridian photometer chain operating in central Canada by Dr. R. H. Eather (under an NSF grant). It was planned to have the instrumented NKC 135 plane fly under the midday auroral region when the Canadian photometer chain was near local midnight.

There are two serious logistics difficulties with such an experiment:

1. Flights must be planned well in advance, and there is no guarantee the ground stations in Canada will be free of cloud cover at that time.
2. There is no guarantee a substorm will occur during the flight time.

Two flights were carried out, but only the January 31 flight marginally met the required conditions. Good data were obtained, but only a very small substorm occurred during the flight period. The auroral changes resulting from the substorm were not significant enough to allow any meaningful conclusions to be drawn. The large data base gathered is presented here as an internal report simply to show capabilities in this area, and outline how data analysis might proceed if a larger substorm event could be recorded in a future experiment.

The location of the Canadian photometer chain (Island Lake, Churchill and Rankin Inlet) is shown in Figure 1. Auroral coverage is between 62° and 78° invariant latitude on cloudless nights. The flight path of the AFGL Airborne Ionospheric Observatory on January 31 is shown in Figure 2. The AIO was under the early afternoon region of the oval from about 0230-0630 UT.

Magnetometer data from Churchill and Baker Lake are shown in Figure 3, and from a chain through central Alberta (courtesy G. Rostoker) in Figure 4. A very weak substorm may be identified as beginning about 0530-0540 UT. on this day, with a stronger storm beginning near 0640 UT. Unfortunately the AIO was not under the midday region for the larger storm, so we are limited to a consideration of the marginally detectable earlier substorm.

The composite keograms in 4278 N_2^+ emision and 6300 UT are shown in Figure 5. Weak, widespread aurora is seen to gradually move south between 00 UT and 06 UT. The only auroral effect seen around the time of the 0530 substorm is an intensification of the southern side of the 4278 keogram. No typical substorm poleward surge was observed (as seen later for the 0640 event). This small intensification is seen on the magnetometer at Churchill, corresponding to an enhenced electroject flow.

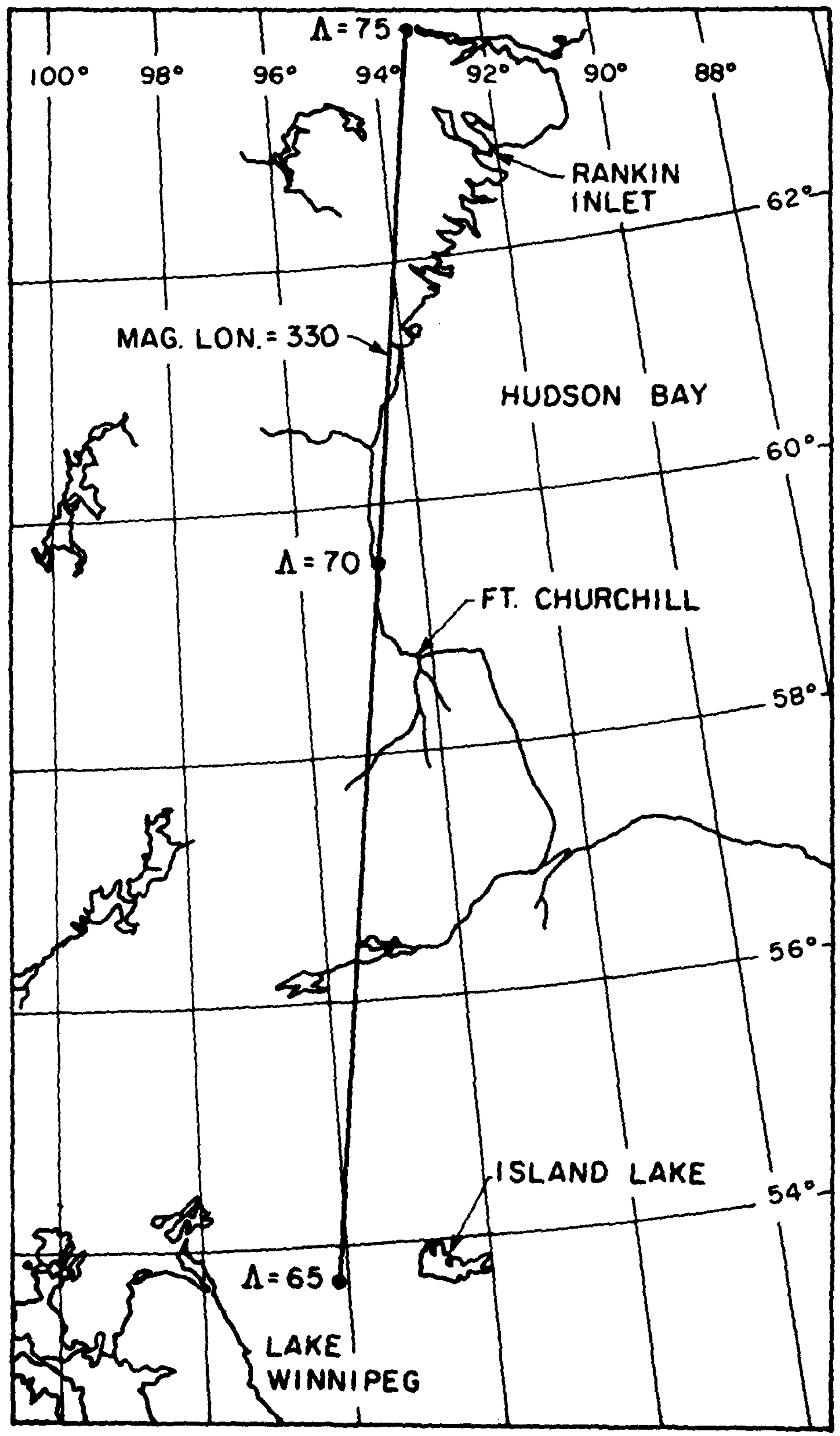
Conductivities integrated across the auroral region were calculated and are shown in Figure 6. Activity around 0530 is evident, but less than for the later event. There is a good correlation between the shape of the calculated conductivities curves and the Churchill magnetograms. This implies the changes in electroject currents can be well understood by a fairly constant magnetospheric electric field driving currents across the varying ionospheric conductivity. The conductivity of course is directly related to the auroral precipitation.

Selected pictures from the All Sky Imaging Photometer on the KC 135 are shown in Figure 7, and an equatorward movement of dayside aurora around 0530 is evident. Keograms prepared from the photometer on the aircraft are shown in Figures 8 and 9, and Figure 10 is a tracing of the relevant features. An equatorward movement of some 2° is seen beginning around 0540. This is larger than would be expected in association with such a small substorm (by a factor of 2), and it is not possible to say whether the movement is entirely substorm related.

Other data collected included solar wind data (M.I.T.) (Figure 11) and particle data from synchronous altitude (L.A.S.L.) (Figure 12). There is a data gap in solar wind coverage at the time of interest. The particle data show small increases around 0540, which might be interpreted as a weak injection.

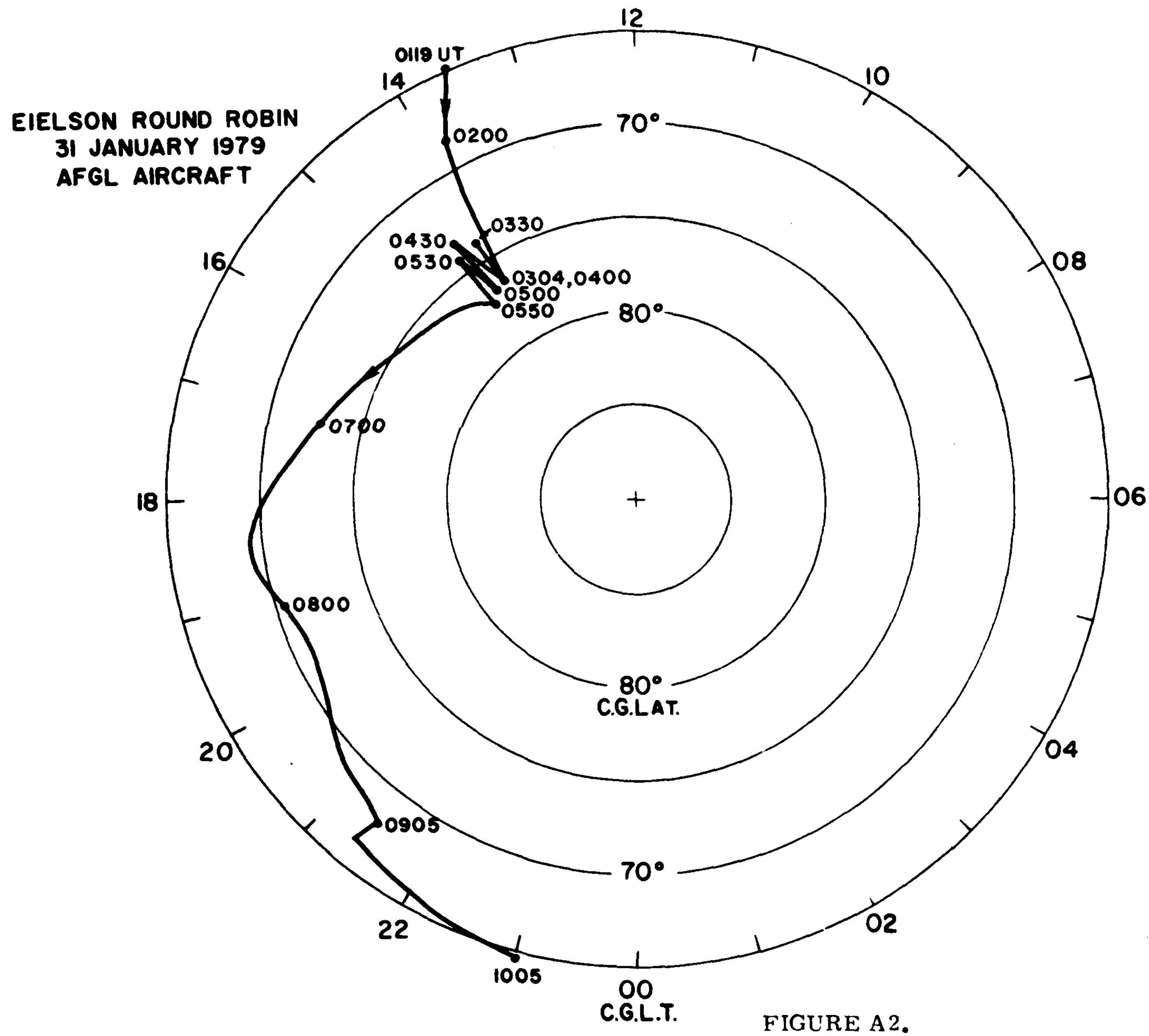
In conclusion, we are unfortunate in not observing a stronger event with more definite auroral effects. The data set shows nothing inconsistant with current understanding, but is not significant enough to allow any new conclusions to be drawn.

The data set here confirm the feasibility of conducting such a complex co-ordinated experiment. Hopefully we might have better luck in the form of a medium-strong substorm on future experiments.



Λ = 75
100°
98°
96°
94°
92°
90°
88°
RANKIN
INLET
62°
MAG. LON. = 330
HUDSON BAY
60°
Λ = 70
FT. CHURCHILL
58°
56°
ISLAND LAKE
54°
Λ = 65
LAKE
WINNIPEG

FIGURE A1.



EIELSON ROUND ROBIN
31 JANUARY 1979
AFGL AIRCRAFT
12
10
08
06
04
02
00
C.G.L.T.
22
20
18
16
14
70°
80°
80°
C.G.LAT.
70°
0119 UT
0200
0330
0430
0530
0304,0400
0500
0550
0700
0800
0905
1005

FIGURE A2.

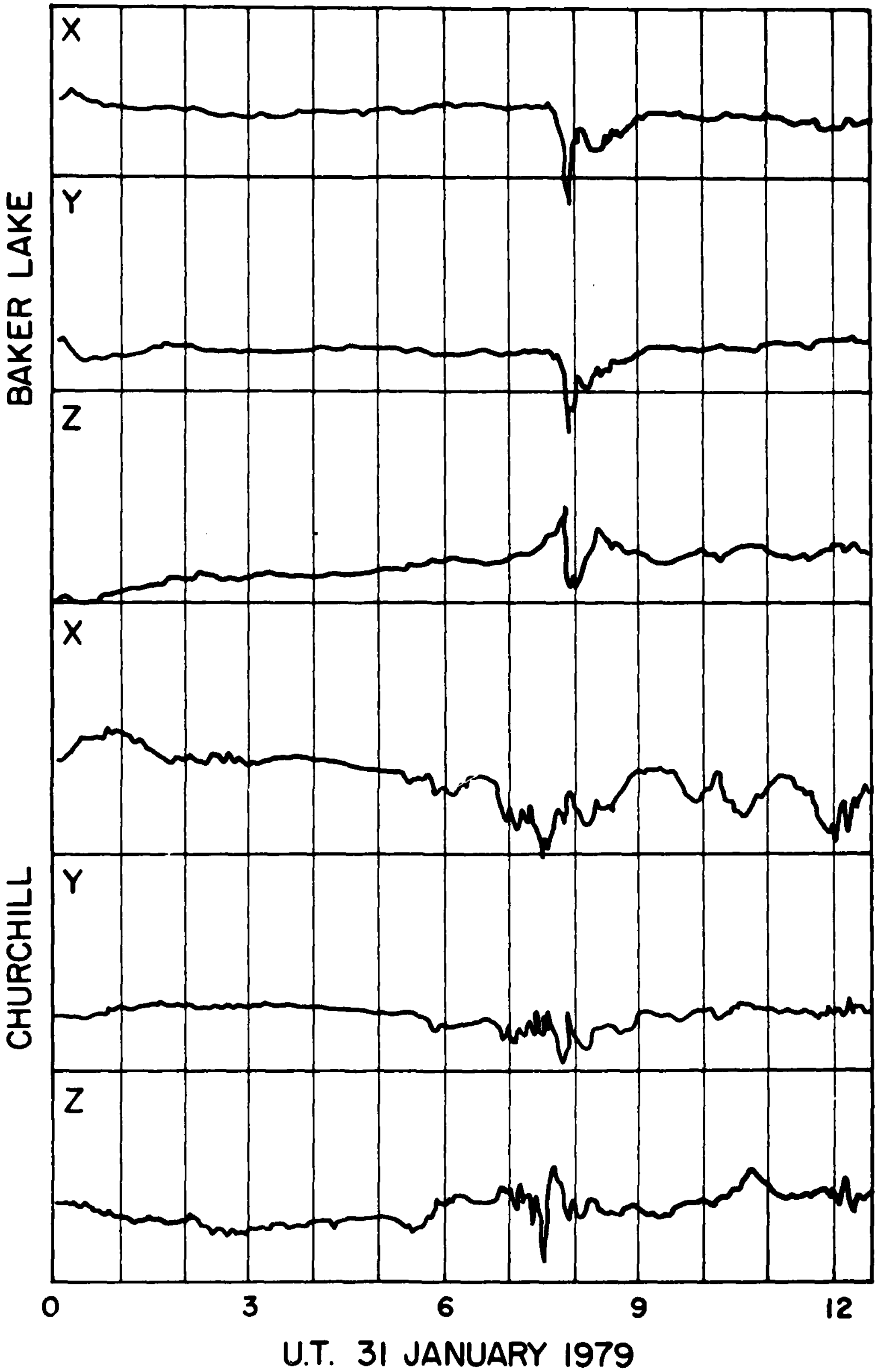


FIGURE A3.

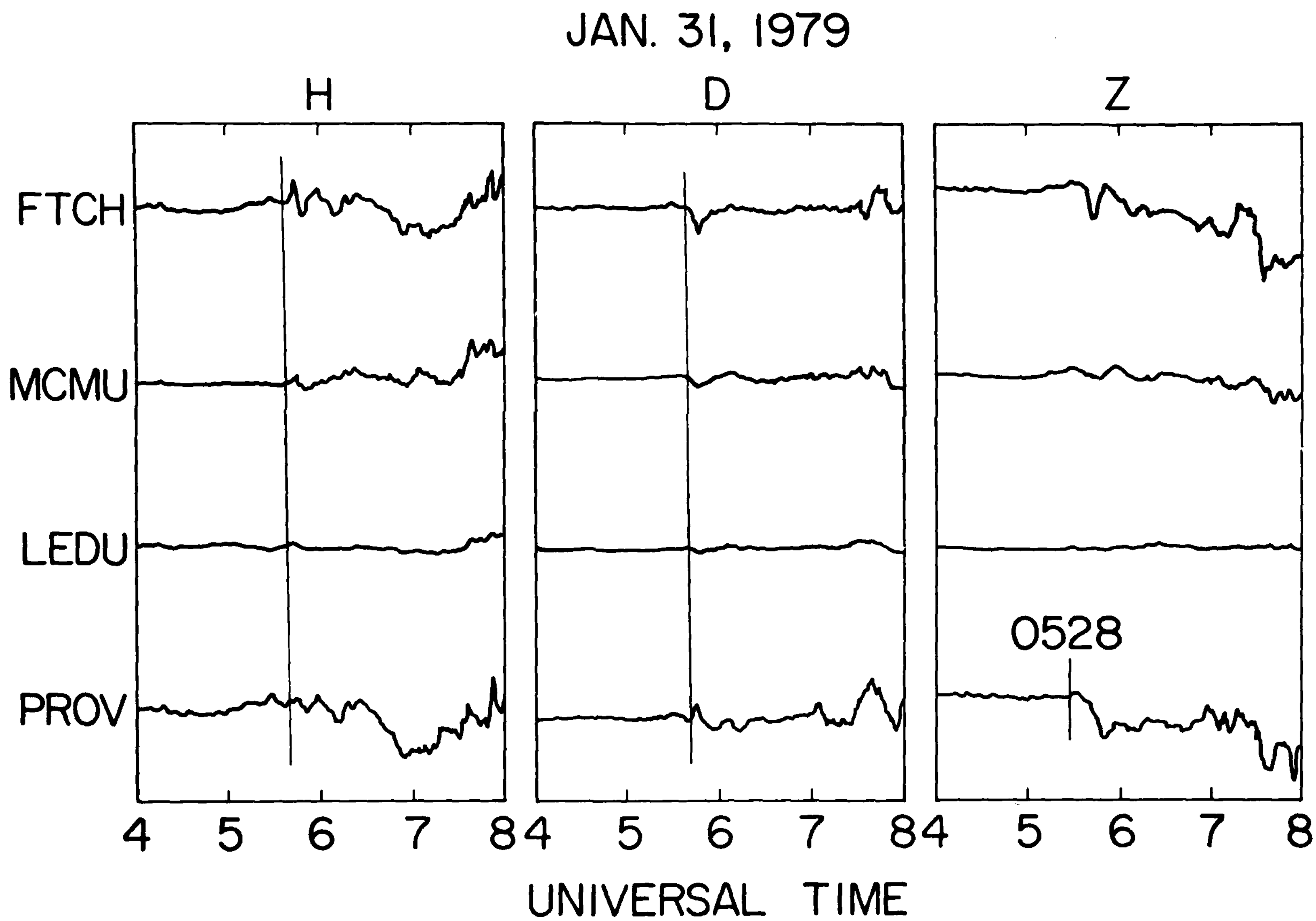

JAN. 31, 1979
H
D
Z
FTCH
MCMU
LEDU
PROV
0528
4
5
6
7
8
UNIVERSAL TIME

FIGURE A4.

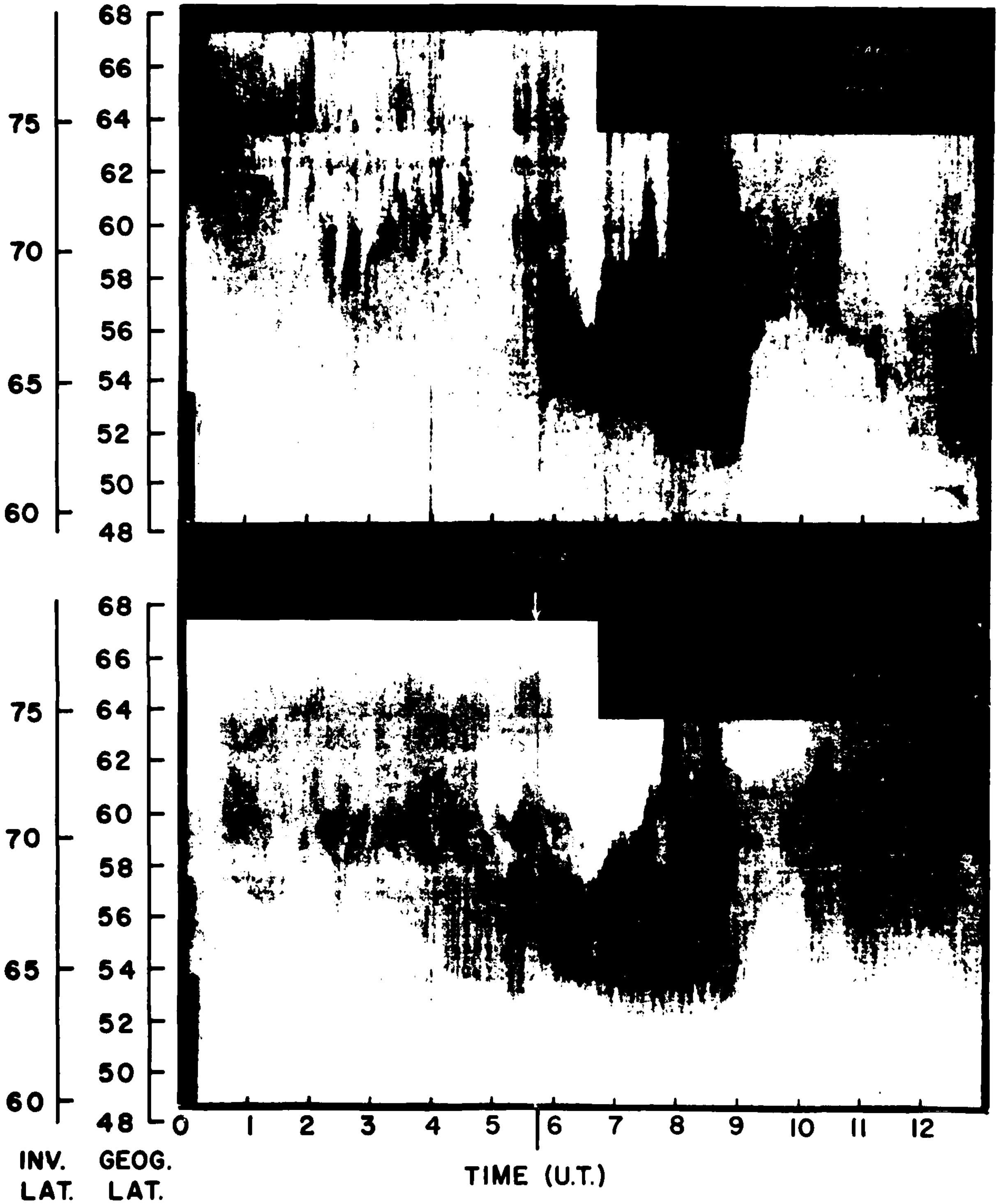

68
66
75
64
62
70
60
58
56
65
54
52
50
60
48
68
66
75
64
62
70
60
58
56
65
54
52
50
60
48
0
1
2
3
4
5
6
7
8
9
10
11
12
INV. LAT.
GEOG. LAT.
TIME (U.T.)

FIGURE A5.

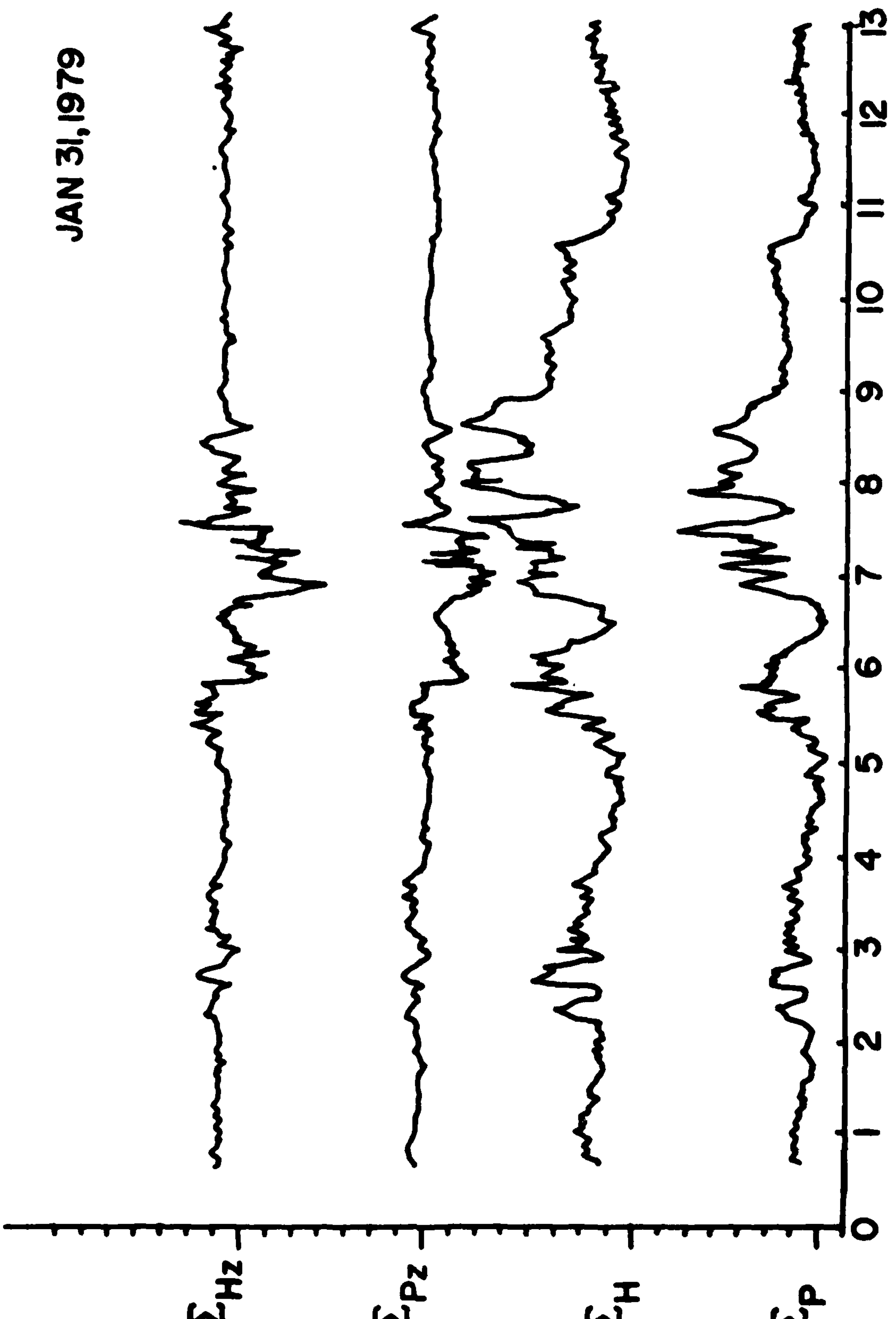

JAN 31, 1979
Σ_{Hz}
Σ_{Pz}
Σ_{H}
Σ_{P}
0 1 2 3 4 5 6 7 8 9 10 11 12 13
TIME (U.T.)

FIGURE A6.

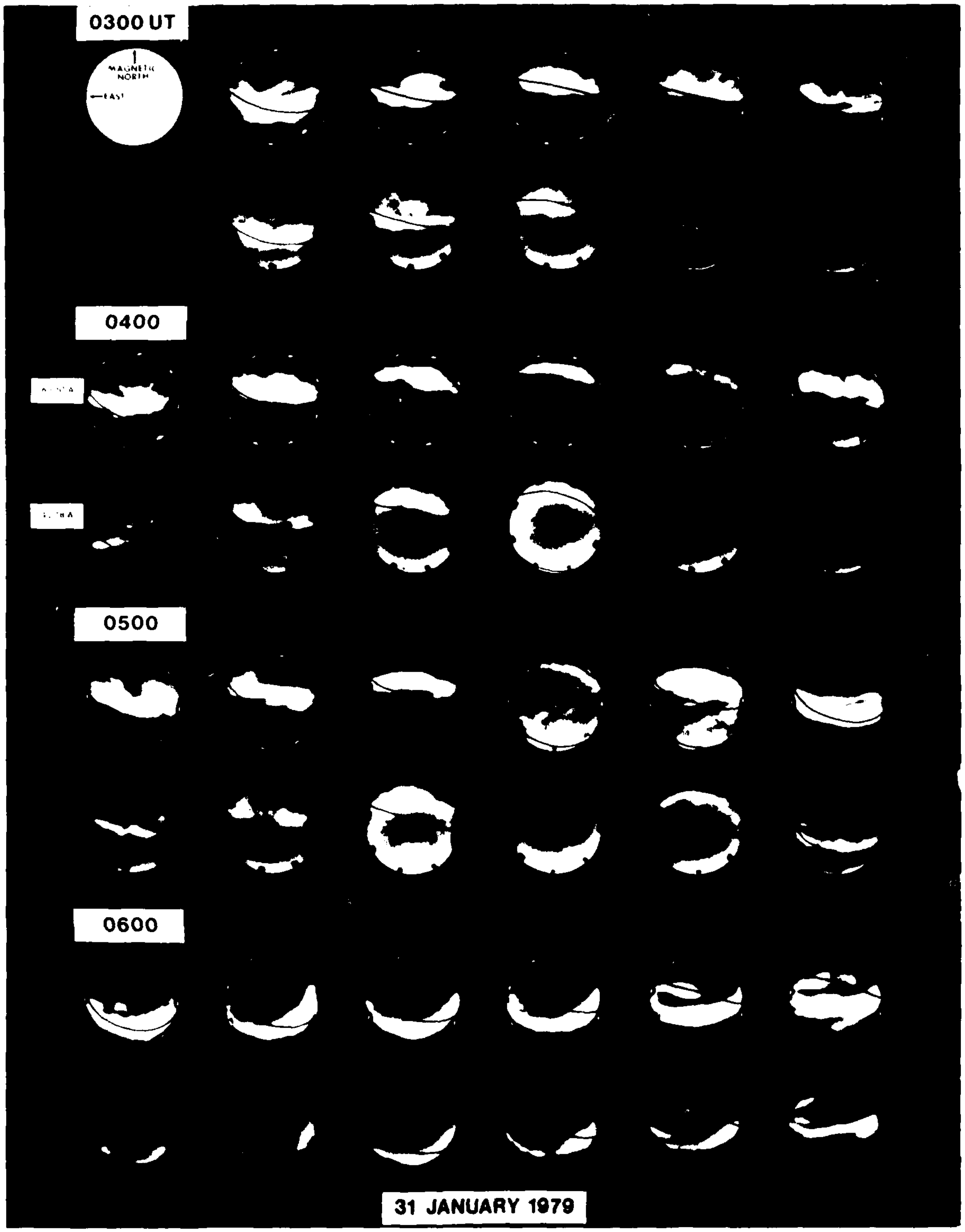


FIGURE A7.

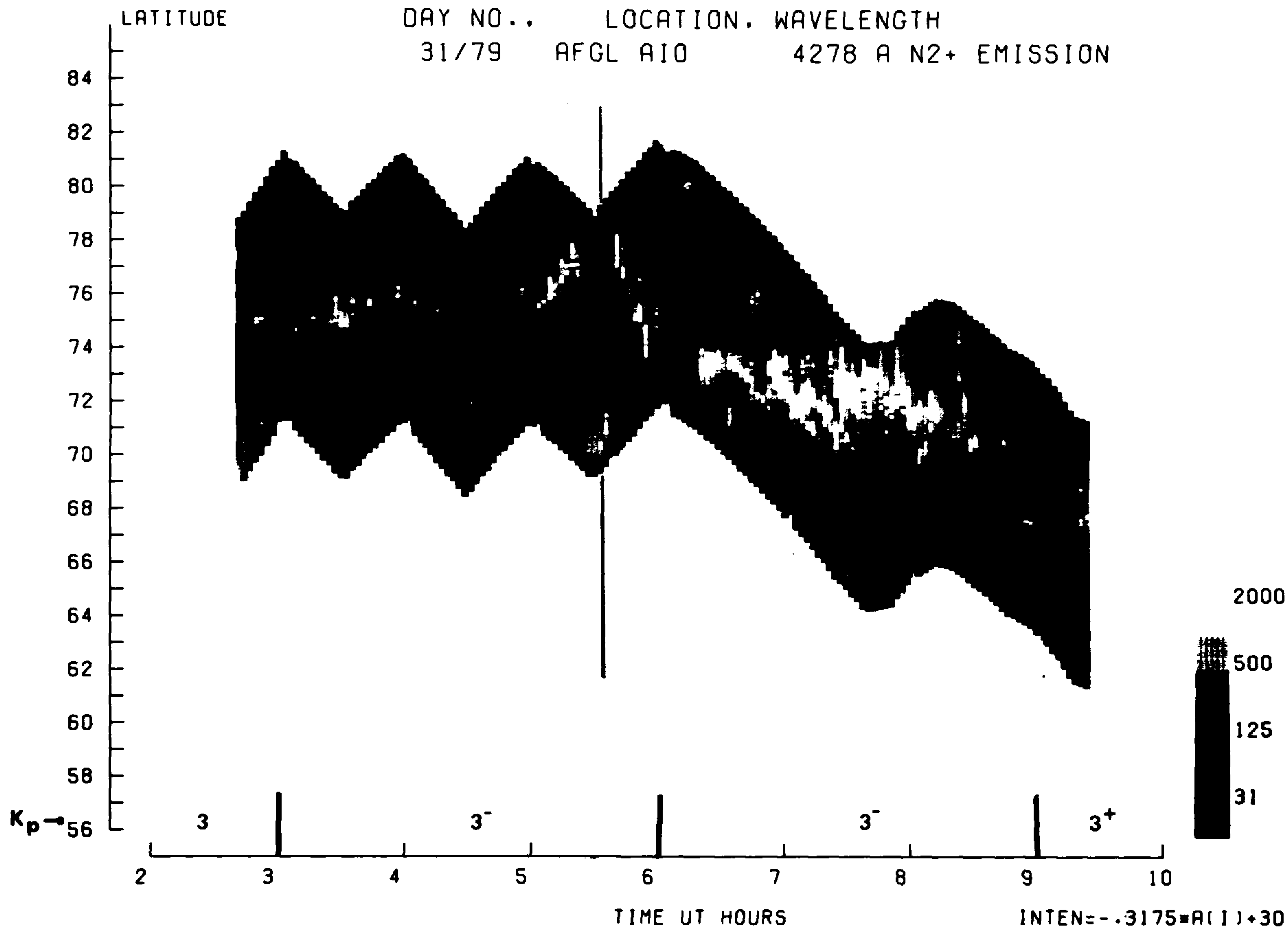

LATITUDE
DAY NO.. LOCATION. WAVELENGTH
31/79 AFGL AIO 4278 A N2+ EMISSION
84
82
80
78
76
74
72
70
68
66
64
62
60
58
Kp→56
3
3⁻
3⁻
3⁺
2
3
4
5
6
7
8
9
10
TIME UT HOURS
INTEN=-.3175*A(I)+30
2000
500
125
31

FIGURE A8.

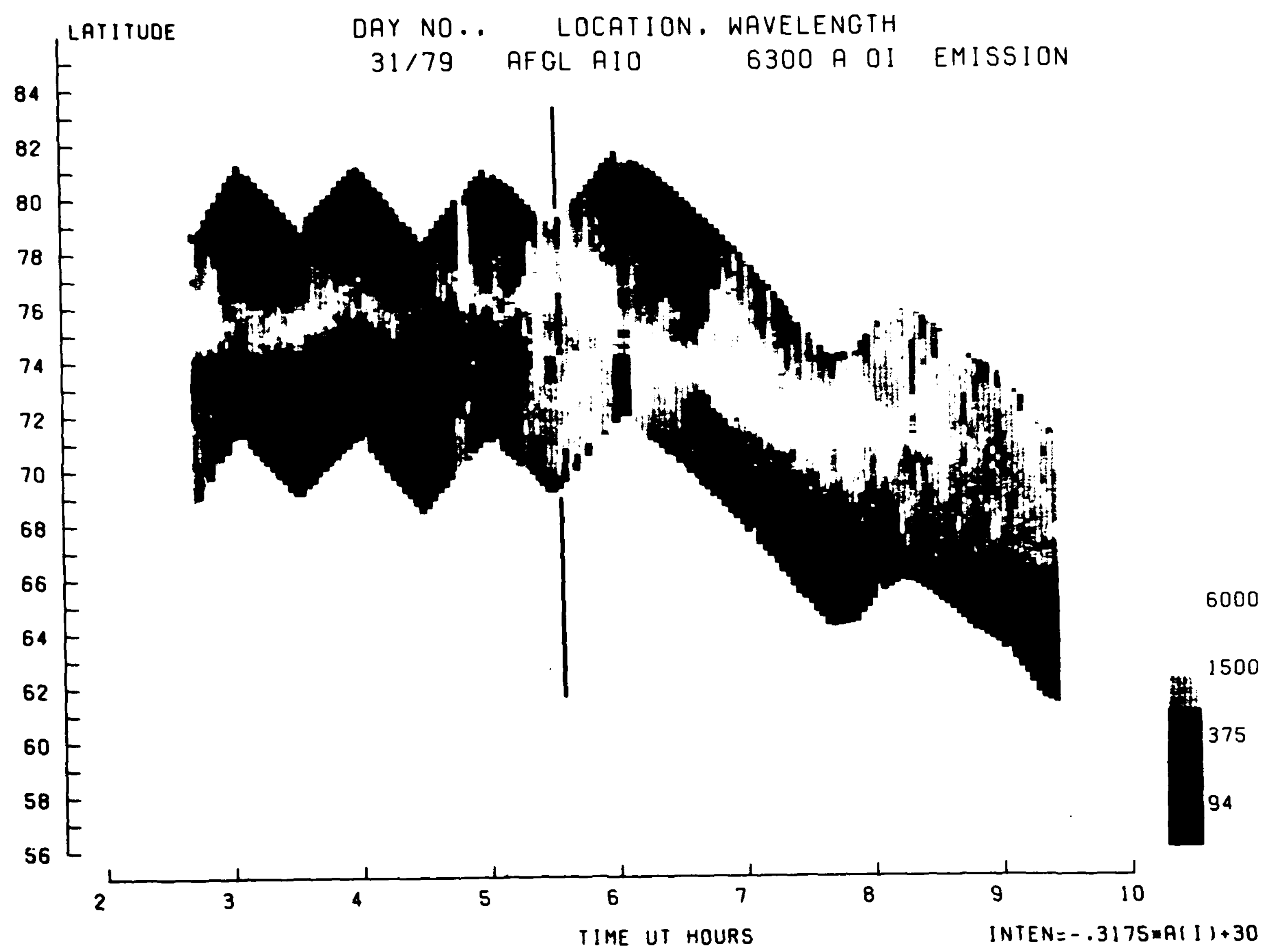

DAY NO..   LOCATION. WAVELENGTH
31/79   AFGL AIO   6300 A OI   EMISSION
LATITUDE
84
82
80
78
76
74
72
70
68
66
64
62
60
58
56
2
3
4
5
6
7
8
9
10
TIME UT HOURS
6000
1500
375
94
INTEN=-.3175*A(I)+30

FIGURE A9.

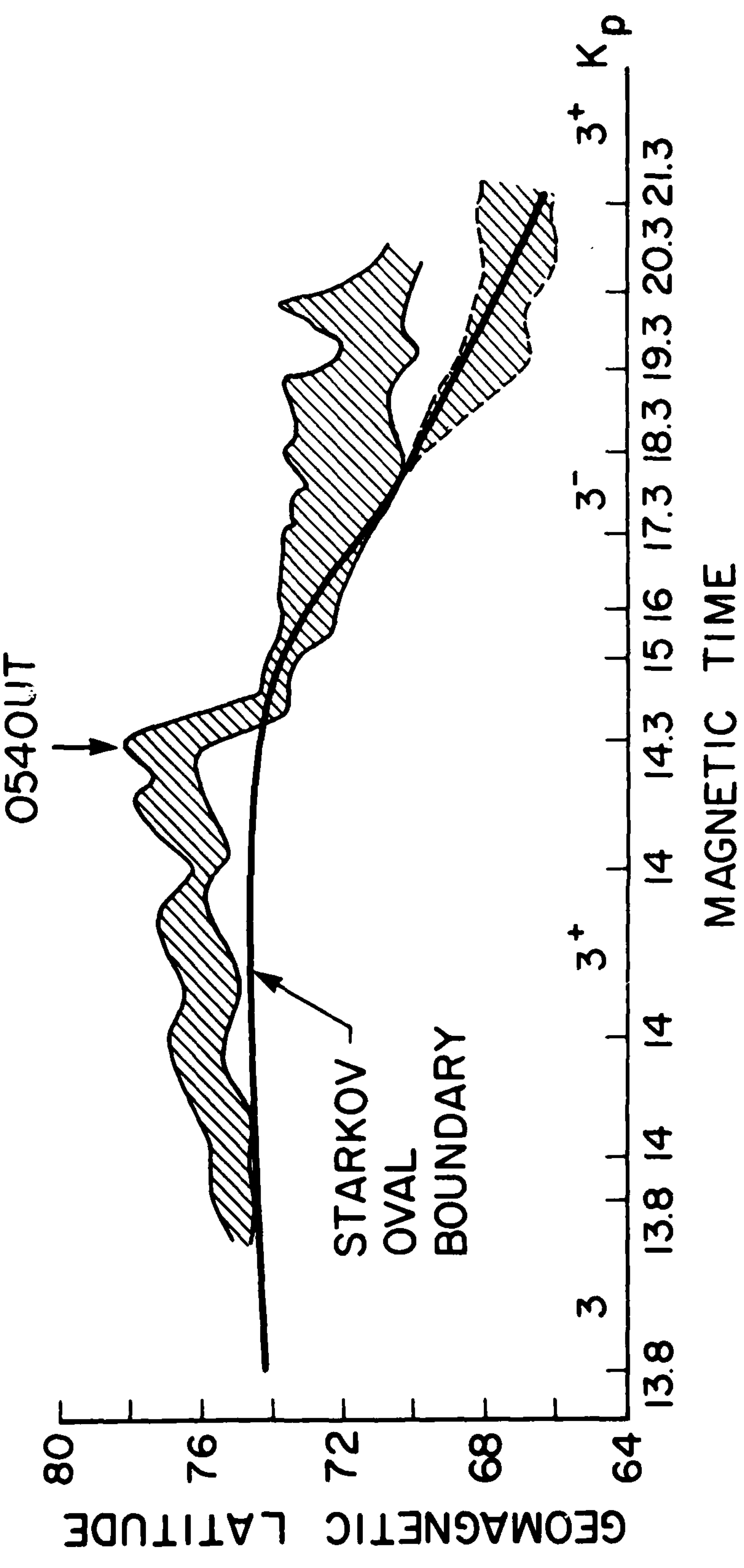

0540UT
STARKOV
OVAL
BOUNDARY
GEOMAGNETIC LATITUDE
80
76
72
68
64
MAGNETIC TIME
13.8
13.8 14
14
14
14.3
15 16
17.3 18.3 19.3 20.3 21.3
3
3+
3-
3+
K_p

FIGURE A10.

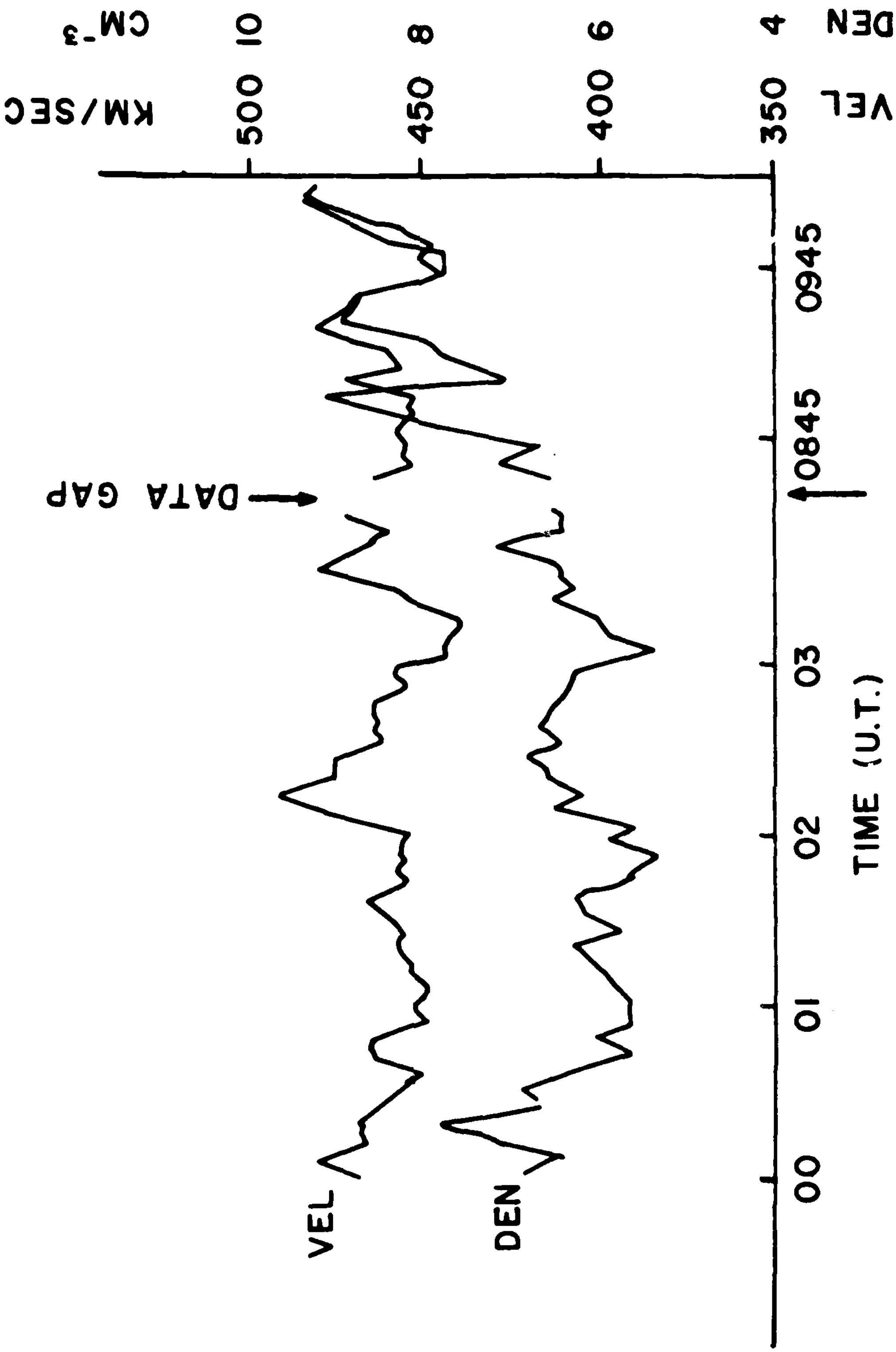

DEN
4
6
8
10
CM-3
VEL
350
400
450
500
KM/SEC
0945
0845
DATA GAP
03
02
01
00
TIME (U.T.)
VEL
DEN

FIGURE A11.

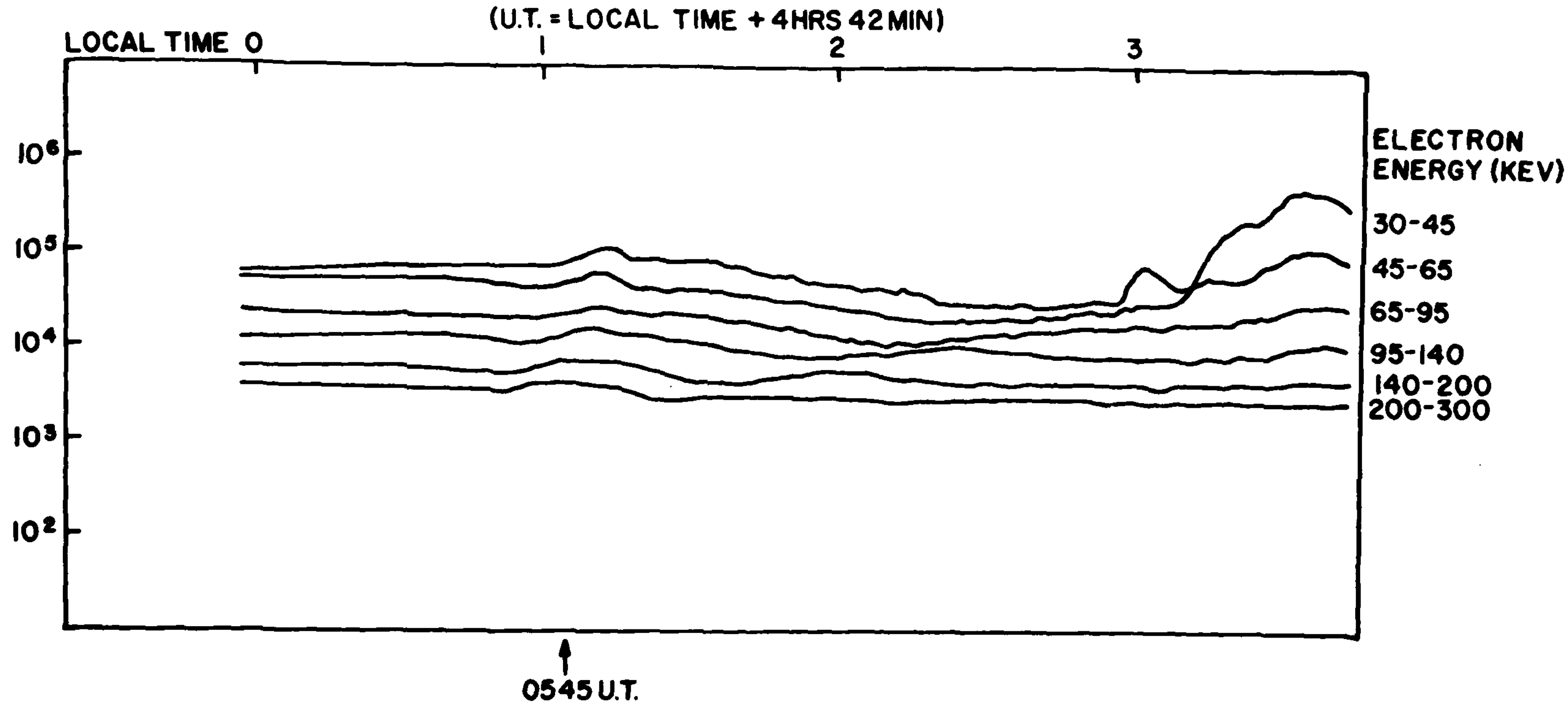

(U.T. = LOCAL TIME + 4HRS 42MIN)
LOCAL TIME 0
1
2
3
10⁶
10⁵
10⁴
10³
10²
ELECTRON ENERGY (KEV)
30-45
45-65
65-95
95-140
140-200
200-300
0545 U.T.

FIGURE A12.

Appendix B

KEO Special Purpose Video Digitizer

CONTENTS

Introduction. The KEO consultants TV digitizer is a hardware system which converts video tapes generated by the Air Force Geophysics Laboratory All Sky Imaging Photometer (ASIP) into computer compatible tape format. The system includes the following components:

1. Video Tape Drive
2. Tape Control
3. Decoder
4. Digital Controller
5. Frame Counter
6. Video Field Memory
7. Buffered Digital Tape Drive

The system schematic is shown on Fig. 1.

The original video is recorded by a video tape recorder in a time-lapse mode. The Tape Control Unit is interfaced with a modified IVC 700 type tape recorder to permit automatic stepping of the time-lapse-recorded single frames. This unit positions the video tape automatically for optimum signal to noise ratio As soon as this condition is attained, a frame detect command is issued to the Decoder Unit.

The Decoder Unit contains the circuitry to decode and "recognize" the encoded video (EVD) by comparison to a pre-selected set of digital parameters. The front panel has controls to set the pre-selected parameters by means of thumb wheel switches. A switch under each digit is used to disable and ignore that digit. An LED display displays the current EVD data. Circuitry is also included to reject repeated identical frames as an operator option. The unit provides a control command to digitize if an appropriate TV field is found, and the EVD data successfully decoded.

On receiving the command to digitize from the Decoder Unit, the Digital Controller scans and clocks the data. The data is recorded by a buffered digital tape drive. The Digital Controller generates a block of I.D. data prior to digitizing the video field. This I.D. block contains the EVD information for the appropriate TV field. On completion of the digitization, and EOF mark is automatically recorded on the digital tape. Each digital TV field will therefore be a digital tape file.

While the Digital Controller is engaged in digitizing the field, a system enable signal goes false and prevents the continuation of the video tape processing.

The Frame Counter is utilized to start and stop the system in an orderly manner, and to permit the hands-off processing of a sequence containing a selected number of TV fields.

2. Operating Instructions

2.1 Input and Output Recorders:

The KEO Video Digitizer is designed to operate with a modified IVC (ITL) 700 or 800 Series time lapse video recorder as input, and a Kennedy buffered continuous recording digital tape drive as output. The video to be digitized must be recorded on the IVC tape format in order to be played back on the modified time lapse video recorder. Different types of digital tape drives can be used with an appropriate adapter cable. A buffer, however, must be included to simplify the interfacing procedure. The system was delivered wired for the AFGL-supplied units (Kennedy 8100 Series recorder and Model 8232 Buffered Formatter).

2.2 Connection of Units:

The connections are as per the connection diagram, Fig. 1.

The video tape recorder (VTR) control cable has to be connected to the VTR and the control select switch has to be switched to external control. The connector and switch are found on the rear bottom plate of the VTR.

The connection to the tape formatter has to be made through the appropriate cable. Video has to be connected from the VTR into the frame memory and into the decoder unit by BNC cable.

The operator will have to use one, or preferably two, video monitors (not shown in Fig. 1). Video monitor 1 is connected to the input side of the frame memory; video monitors 2, if available, should be connected to the video output of the frame memory.

2.3 Functional Operation:

The system searches video tapes and identifies the appropriate frames for digitization. Once such a frame is found, it is recorded in the frame memory and the contents of the frame memory are transferred to the digital tape. One field of video produces one file of digitized data.

If the digital tapes are made on the KEO ASIP, then they use ID bars recorded on the tape which are used by the digitizer system to:

(a) select frames for digitizing

(b) record the digital code represented by the bars on the first record (block) of each file.

2.4 Digital Output Data Format:

Each TV frame is contained in one data file on digital tape. The data is in the form of 6 bit bytes on the (7 track) tape.

The first block contains the EVD data. Each hexadecimal character occupies the first least significant bit of the byte. The number of byte EVD characters is ...... The number of bytes in the first EVD block is ...... The video data is digitized into 6 bit words. Each 6 bit word occupies one byte on the digital tape. Each TV line corresponds to one data block. There are 256 samples per TV line and therefore there are 256 bytes per data block.

The number of data blocks of digitized TV lines depends on the setting of the line selector thumbswitch on the Digital Controller Unit. The thumbswitch represents the number of TV lines to be skipped and not digitized. If the switch is set to zero, then all 256 TV lines in the field memory are digitized. The total number of blocks per file, including EVD data, is

$$\frac{256}{n+1} + 1$$

where n is the setting of the line selector thumbswitch.

2.5 Controls and their Functions:

2.5.1 Tape Control Unit:

This unit positions the video tape on the VTR by driving the capstan motor. This motor is a stepping motor and the tape control unit provides the appropriate number of pulses to step forward one field for each frame step command.

The video is recorded on the tape on crosswise slanting tracks. In order to stop in the exact place of maximum signal to noise ratio, the tape control unit is provided with a signal from the video recorder's demodulator to check that the FM corner level in the playback signal is above a certain threshold. This level is used in the Tape Control Unit to detect whether the frame is a "good" frame with high enough signal to noise ratio and without the presence of noise bars Dependent on the conditions of the video tape and other factors, the demodulator carrier frame detection circuit may occasionally accept a frame which is substandard. Such errors are an inherent problem of helical scan tape recordings and do not necessarily imply system malfunction.

SW Internal/External: In the internal position, the single frame switch enables the operator to "single frame" forward on the tape. On "external," the unit passes control to the decoder unit.

Single Frame Momentary Switch: To advance one frame on video tape. The indicator light shows when the tape is being searched (light is off) or when tape is being read or stopped (light is on).

In the external mode, frame advance takes place on command by the decoder.

2.5.2 Decoder:

The function of the decoder is to decode the Encoded Video Data (EVD) bars, display them on the front panel, and enable the operator to make selections depending on the information contents of the EVD bars.

LED Display groups 4-3-3-3-:

These display in numerical form the information content of the ID bars.

Group 1 HEADING

Group 2 TIME

Group 3 DAY NUMBER

Group 4 ..... Auxiliary data group; Exposure duration, Frame I.D., filter.

Three Way Thumbswitches:

These allow the selection of a video field by the comparison of the thumbswitch with the LED display group. There are only three digits on the thumbswitch to input data for comparison. These three digits can be assigned to any three LED display digits.

The digits in the LED display are selected by the switch under each digit. If the switch is down, the digit is ignored by the decoder. If the switch is up, then that digit is compared to one digit of the thumbswitch and if the digits are equal, digitization will proceed. The order in which the thumbswitch digits are associated with the LED digits is illustrated in the example below.

Consider the settings shown in the Figure 2. The LED digits are shown in four groups. In the example, three switches are up: the 2nd in Group 1 (Heading), the 3rd in Group 2 (Time), and the 2nd in Group 4 (Aux Data). The assignment for comparison is shown by arrows. Thus, if the displayed digits on the thumbswitches and the LED display are equal in all three cases, then that frame is selected.

The thumbswitch digits are selected in order from left to right. The LED digits within each group are also selected from left to right. The selection between the LED display groups is in order according to the LED Group number. See Figure 2.

The most significant thumbwheel digit (left most) is compared to the digit of the LED display under which the switch is on and which is in the lowest-numbered group. Digits within each group rank from left to right. In our case, the first digit in Group 1 is switched off and the middle digit is used for comparison with the digit of the thumbwheel switch. The next thumbwheel switch digit is compared to the next lower ranking LED digits since in Group 1, the third least significant LED digit is off, the next group, Group 2 (TIME) is taken into consideration. In this group, the third digit (tens of minutes) is the only one on. Therefore, this will be compared to the middle digit of the thumbswitch. The least significant thumbwheel digit is compared to the second digit in Group 4 (because all of Group 3 are off) and the first digit of Group 4 is also off.

Let us assume that the thumbswitches are set 0,0,1. The system will scan the video tape and digitize all frames in which the middle digit of the heading is zero, the tens of minutes are zero (i.e., the first ten minutes of data in each hour) and the second digit of the auxiliary data is 1.

Switch S1

If S1 is down, digitization will take place every time valid comparison occurs. If S1 is up, digitization will take place only when comparison is valid and the frame is encountered the first time. The reason for including S1 is that during time lapse recording data taking, the same field is often recorded many times over on the tape. This permits the rejection of the repeated frames.

Thumb Switch (single digit)

This enables the operator to digitize only a selected sample by dividing the valid comparisons by the set value, i.e., digitize every n^{th} valid frame where n is the thumbwheel setting. n represents the number of fields skipped, e.g., n=0, no fields skipped; n=1, every other field, etc.

Fast and Normal Mode Switch:

This switch enables the operator to scan the tape quickly. In fast mode, the tape will advance rapidly to the place where the time is equal to the selected value on the 4-digit thumbswitch. The tape will then stop, and system is ready for digitization.

Run halt Switch

Up-system will run; down-system will complete last field, then stop; Center positions - decoder passes control to frame counter.

2.5.3 Frame Counter:

3-way Thumbswitch:

Enables setting the number of frames to be digitized. Typical computer convention is used, counting starts at zero, and not one.

Momentary Switch:

Loads contents of thumbswitch and starts operation.

2.5.4 Digital Controller:

This is the most complex of the 4 units. It performs the following functions:

(a) Formats the encoder bars and records them in the first record (block) in each digital picture file.

(b) Reads digital data out of video field memory and clocks it out to the buffer of the digital tape drive.

(c) Divides the number of TV lines by the number shown on the front panel switch to select TV lines for digitization.

This unit has only one operator function:

1 digit Thumbswitch:

Divides the number of TV lines for recording on the digital tape and skips the in-between ones. This is another feature to increase the speed of the process of digitizing only representative samples of the video field. The setting is from 0 to 15, representing the number of skipped TV lines.

3.0 Step by Step Operating Procedure

1. Connect all cables
2. Turn on power to all units, including VTR and Field Memory
3. Initial switch settings: Tape Control EXT
   Decoder HALT
   S1 DOWN
4. Load digital tape drive. Switch it to ON LINE. Check switch on back of VTR is in external position. Turn VTR to PLAYBACK. Tape should engage but not move.
5. Set time for starting digitization on 4-digit thumbwheel switch on DECODER front panel.
6. Select FAST. Tape should move forward to selected time period on tape and stop when time code equals selected time.
7. Select frames to be digitized. Refer to instructions on DECODER operation. Switches under LED display digit are used to reject or include digit for comparison with three digit thumbswitch. Assignment order is as per group number on Fig. 2. The digits within one group are assigned from left to right.
8. Select number of frames to be digitized on frame counter. Select number of lines to skip with thumbswitch on digital controller.
9. Select number of frames on frame counter and enter. Video tape should move forward and digitization should commence. Light on tape control should go out while tape is moving and come on as tape stops. Operation halts when required number of frames are digitized.
10. New periods may be selected. Note that VTR will not reverse so selected times for fast forward must be ahead of time shown on tape. Note: VTR will obey its own fast reverse and forward push button controls regardless of the position of the external drive switch.

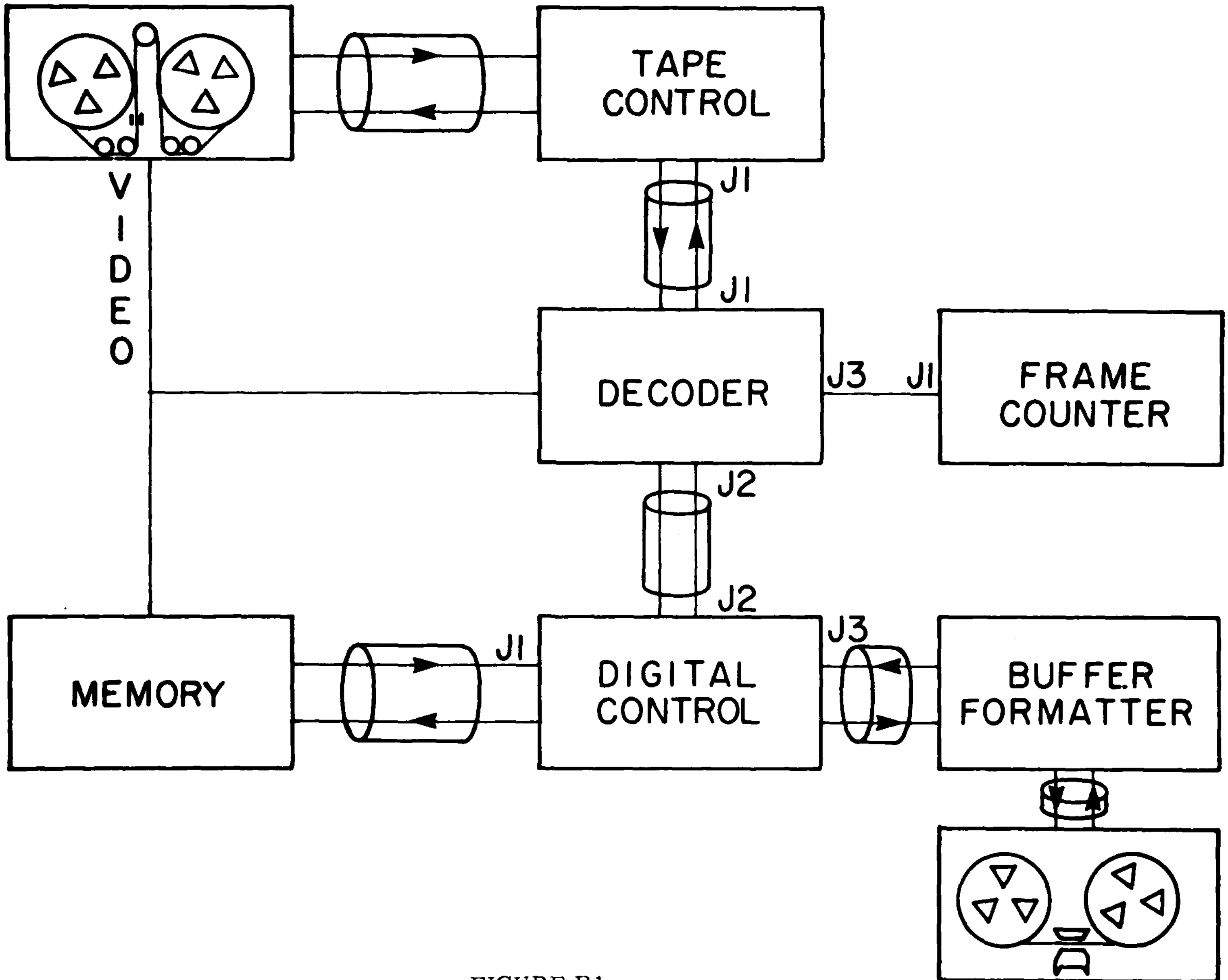

TAPE CONTROL
J1
J1
VIDEO
DECODER
J3
J1
FRAME COUNTER
J2
J2
J1
J3
MEMORY
DIGITAL CONTROL
BUFFER FORMATTER

FIGURE B1.

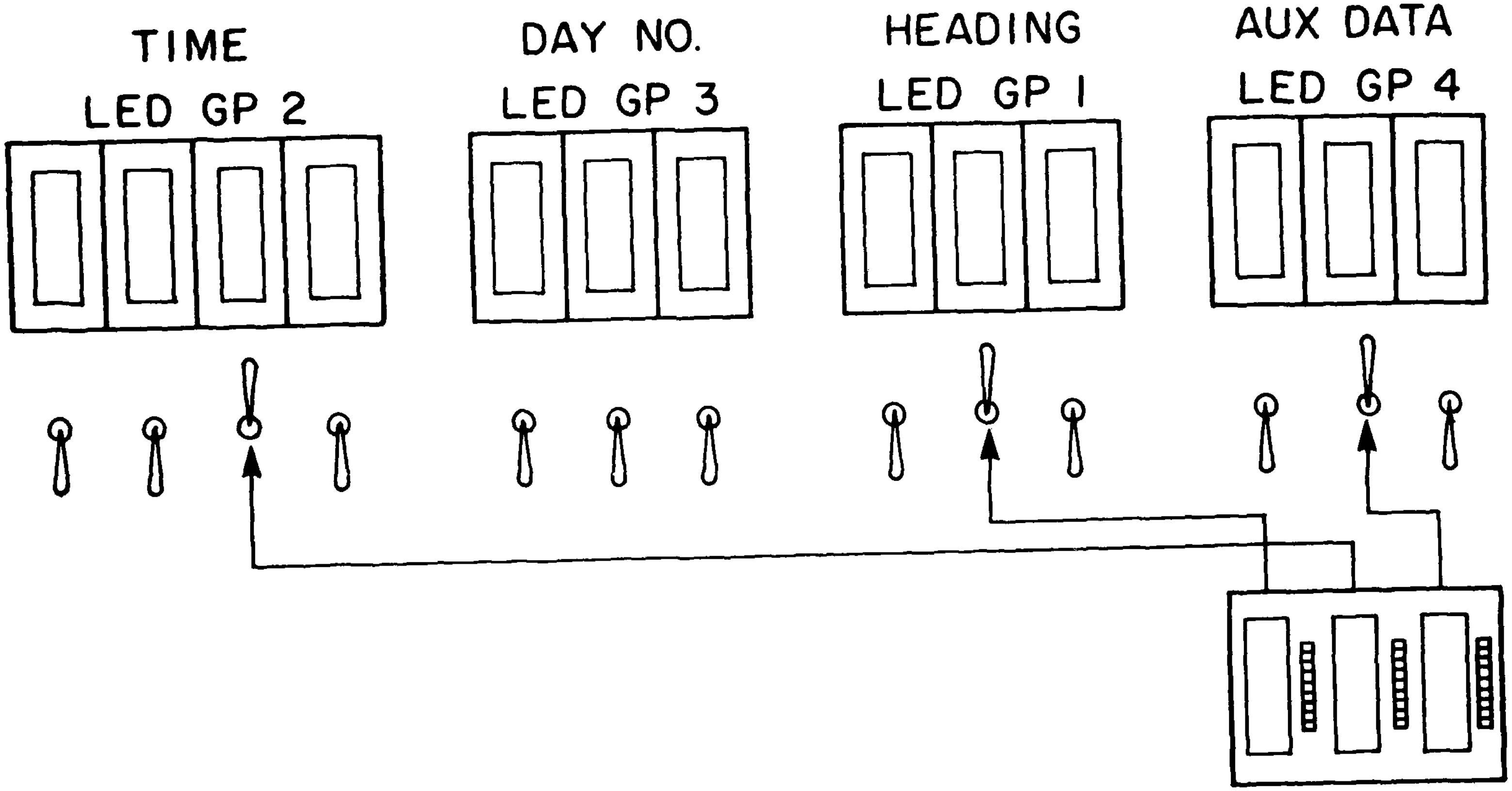


FIGURE B2.

Appendix C

KEO CONSULTANTS

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ALL-SKY IMAGING PHOTOMETER SOFTWARE

This program package analyses digitized all-sky imaging photometer picturss and plots various derived auroral parameters (emission intensities, ratios, energy, ionization rates, conductivity, etc) on various mapping grids (geographic, geomagnetic, polar, spherical projection, mercator, etc.).

A brief summary of the analysis procedure follows:

1. Main program reads in (from cards) $5^{o}x5^{o}$grid values for magnetic field declination and inclination. Subroutine INTERP is then called to interpolate for 1^{o} grid points.
2. The location of good data on the video image is defined by reading in (from a card) the center position and size of the auroral image. Plane position and heading are also entered from this card, together with an assumed emission height. (It is expected that this manual step will be eliminated by software analysis as experience is gained with actual data tapes.)
3. If the auroral image area is not exactly circular, subroutine ELLIPS is called to correct for image distortion.
4. The location of each data pixel (row and column numbers) is then given to subroutine GEOG, which calculates the geographic coordinates of the field-line projection of the pixel point to the earth's surface.
5. Subroutine GEOM then converts these coordinates to corrected geomagnetic coordinates.
6. The maximum and minimum coordinate values in the selected plotting format are used to define plotting range . Any pixels in this range that do not contain a data point are filled by interpolation (in two directions) by subroutine PIXFIL.
7. Grid lines are added to the map by calling subroutine GRID.
8. The data is plotted in either gray-scale format (subroutine PLOTG) or as a contour map (subroutine PLOTC).
9. Analysed images may be stored on disc to allow image subtraction or division before plotting (subroutine STORE).

Appendix D

All-Sky Imaging Photometer -- Calibration Report

The calibration curves attached allow derivation of absolute auroral or airglow intensities from the measured video level. In addition to the video volts, the following data is needed to derive absolute intensity:

1. High voltage level
2. Exposure time
3. Wavelength of spectral features
4. Position in field-of-view

Figure 1: Voltage Linearity.

Shows how the relative video level varies with changes in high voltage setting for a given input light intensity, and for various exposure times. It may be seen that the dependence is non-linear, with a given increase in high voltage setting producing greater relative increase in video level at lower video levels than at higher video levels.

Figure 2: Exposure-Time Linearity.

Shows how the relative video level varies with changes in exposure time for a given input light intensity and for various high voltage settings. There is a better linear relationship than in Figure 1, but saturation effects become evident when the video level exceeds about half the maximum level.

Figure 3: Absolute Calibration Curves.

Shows a series of absolute calibration curves for various high voltage settings, and covering the full range of useable exposure times. The intensity (in R) refers to intensity after the filter. Thus these curves can be used for any filter, and intensities related to actual auroral or airglow intensities by multiplying the intensity scale by $S(\lambda)[\int I(\lambda)\ T(\lambda)\ d\lambda]^{-1}$, where $I(\lambda)$ is the normalized line profile of the emission feature, $T(\lambda)$ the filter transmission curve, and $S(\lambda)$ the relative spectral sensitivity (Figure 4).

Table 1

λ	$\Delta\lambda$ Filter	% T	$[\int I(\lambda)\ T(\lambda)\ d\lambda]^{-1}$	$S(\lambda)$	Product
4278	38 A	34	2.94	2.69	7.90
4861	34	60	1.67	1.50	2.50
5577	30	65	1.54	1.00	1.54
6300	30	74	1.35	0.73	0.99

The reduced sensitivity (by a factor of ∿8) between blue and red results from

a) Reduced filter transmission at blue

b) The photocathode spectral sensitivity of the first image intensifier, and spectral transmittance of the various optical components.

NB: These absolute intensity values are based on the AFGL supplied DR-2 Light Source. This source should be intercompared with a recently calibrated source.

Figure 4: Relative Wavelength Sensitivity.

Shows the relative wavelength sensitivity of the complete electro-optics system (after the filters), normalized to sensitivity at 5577 A.

Figure 5: Vignetting.

Shows vignetting (of a factor of ∿3) between the center and edges of the field. This is primarily in the first (fisheye) lens.

EXAMPLES: a) A 6300 OI feature gives 0.32 V video level at a high voltage setting of 940, an exposure time of 1 sec, and is located at a zenith angle of 60°. What is the absolute intensity?

Fig. 3D gives, for exposure time of 60 fields, that 0.32 V video corresponds to 143 R. From Table 1, for 6300, this corresponds to 141.6 R. From Fig. 5, at 60°, vignetting reduces transmission to 63%. Therefore, Absolute Intensity = 225 R

EXAMPLES: (cont.)

b) A 4279 feature gives 0.23 V video level at a high voltage setting of 920, exposure time of 1/2 sec, and is located at a zenith angle of 30°. What is the absolute intensity?

Fig. 3C gives that 0.23 V video at 920 HV and exposure time of 30 fields corresponds to 370 R. From Table 1, for 4278, this corresponds to 2923 R. From Fig. 5, at 30°, vignetting reduces transmission to 90%. Therefore, Absolute Intensity = 3.25 kR.

Figure 6: Built-In Calibration Source.

These curves show the video level generated by the built-in calibration source for various high voltage settings over the range of exposure times. These curves may be used to set the TV camera controls as follows:

a) Set PED full anti-clockwise
b) Adjust VIDEO GAIN until video out agrees with data in Figure 6 -- this will occur for ~1/4 turn clockwise.

The curves of Figure 6 may also be used to estimate the accuracy of the calibration procedure. The table below shows the derived intensity (from Fig. 3) of the light source for the indicated combinations of exposure and high voltage.

Table 2

HV \ EXP. TIME	120	60	30	15	8	4	2
880	205						
900	190	205					
920		190	200	220			
940		190	200	195	220		
960			210	205	270	215	
980			195	210	195	205	190
1000				210	215	220	205

Figure 6: (cont.) It may be seen that all values fall within the range of 205 ± 15 R, indicating an approximate accuracy of determination of absolute intensity from the calibration curves of ± 7.5 %. At least half of the source of such error is in the difficulty in measuring the video level because of the noisiness of the video trace on the oscilloscope.

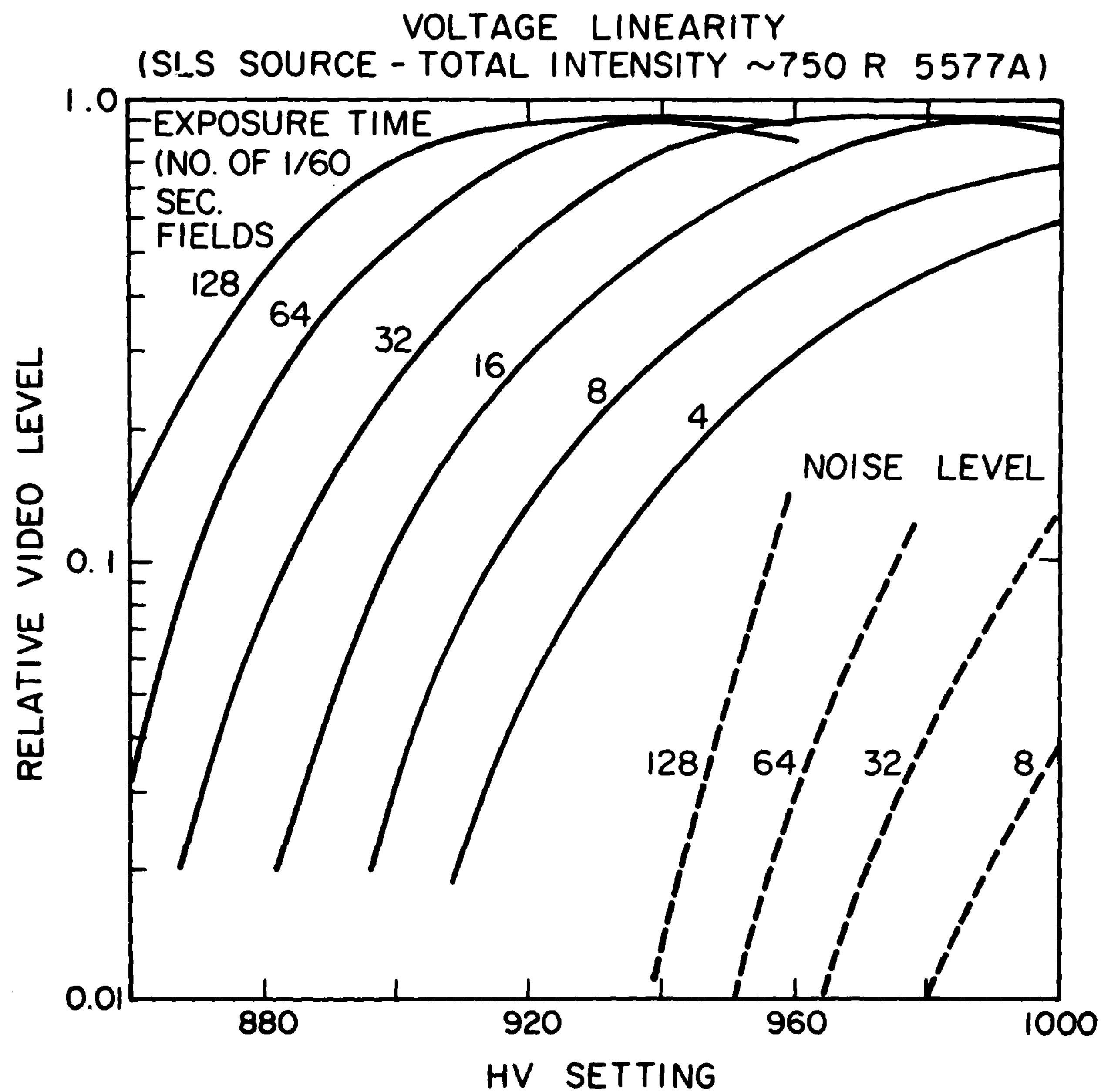
Maximum Sensitivity:

At maximum HV and for 2 sec integrations, the sensitivity of the system (to give a recognizable image above noise) at operating temperature of ~ 20°C is ~ 5 R (6300 A) $\rightarrow$ 20 R (4278 A).

For real-time operating, intensities need to be ~ 150 R (6300 A) $\rightarrow$ 1 kR (4278 A).

Dynamic Range:

For a given HV setting and a given exposure time, useful dynamic range is about 10:1. By programming a series of exposure times, the dynamic range may readily be increased to 100:1. Further increase in dynamic range must then involve changing the HV level.


VOLTAGE LINEARITY
(SLS SOURCE - TOTAL INTENSITY ~750 R 5577A)
EXPOSURE TIME
(NO. OF 1/60
SEC.
FIELDS
128
64
32
16
8
4
NOISE LEVEL
128
64
32
8
1.0
0.1
0.01
880
920
960
1000
RELATIVE VIDEO LEVEL
HV SETTING
FIGURE D1.

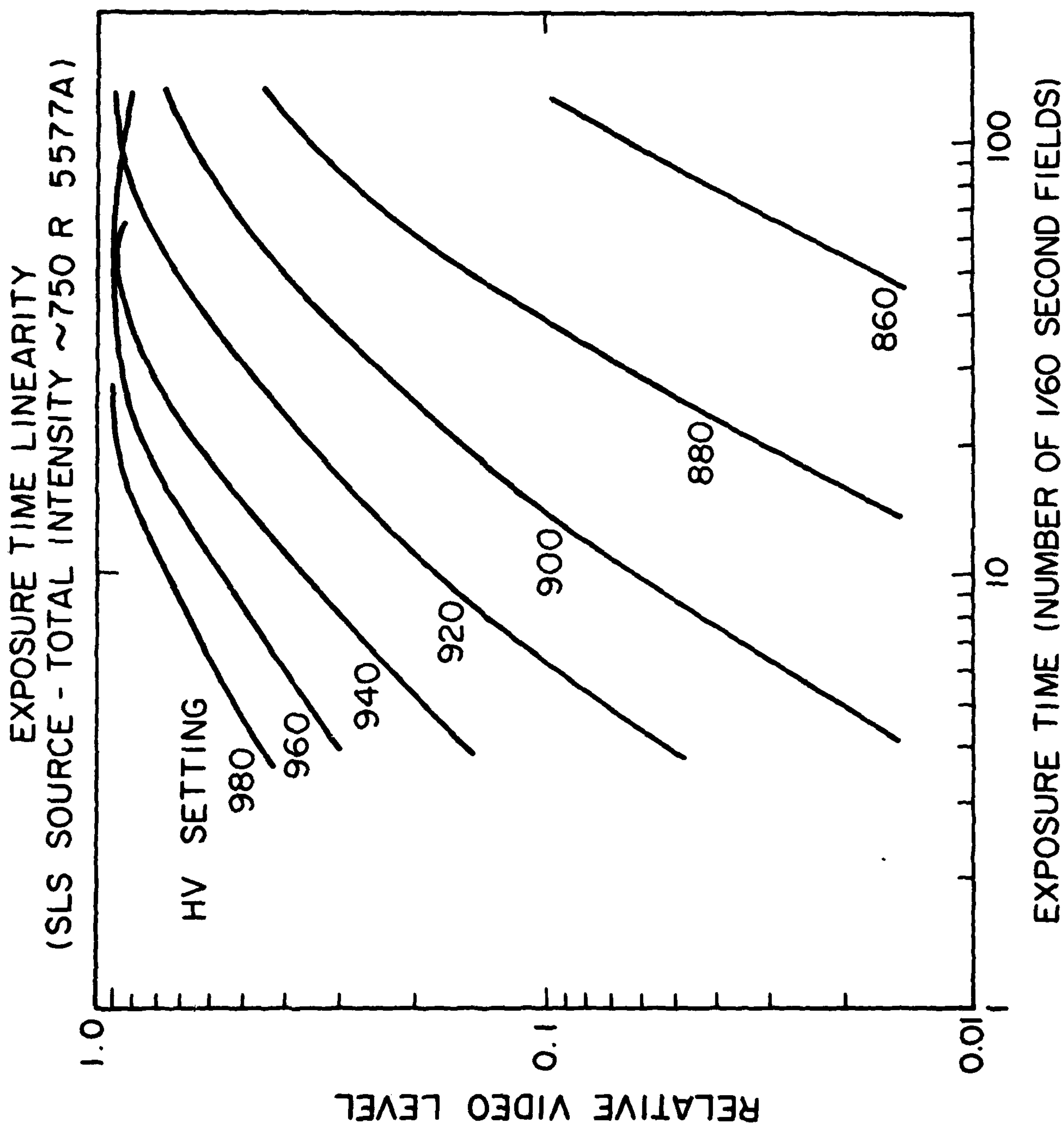

EXPOSURE TIME LINEARITY
(SLS SOURCE - TOTAL INTENSITY ~750 R 5577A)
HV SETTING
980
960
940
920
900
880
860
1.0
0.1
0.01
RELATIVE VIDEO LEVEL
1
10
100
EXPOSURE TIME (NUMBER OF 1/60 SECOND FIELDS)

FIGURE D2.

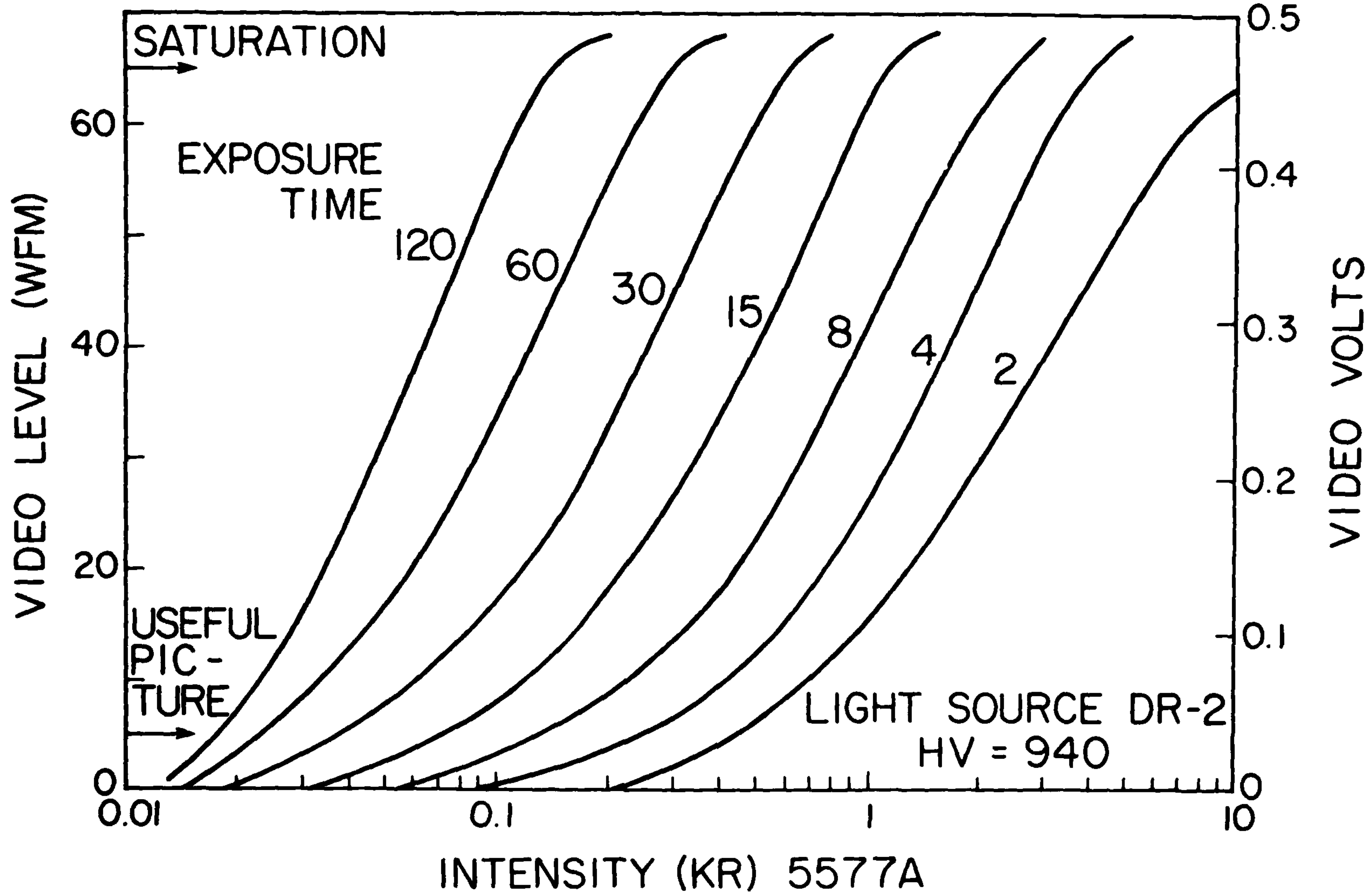
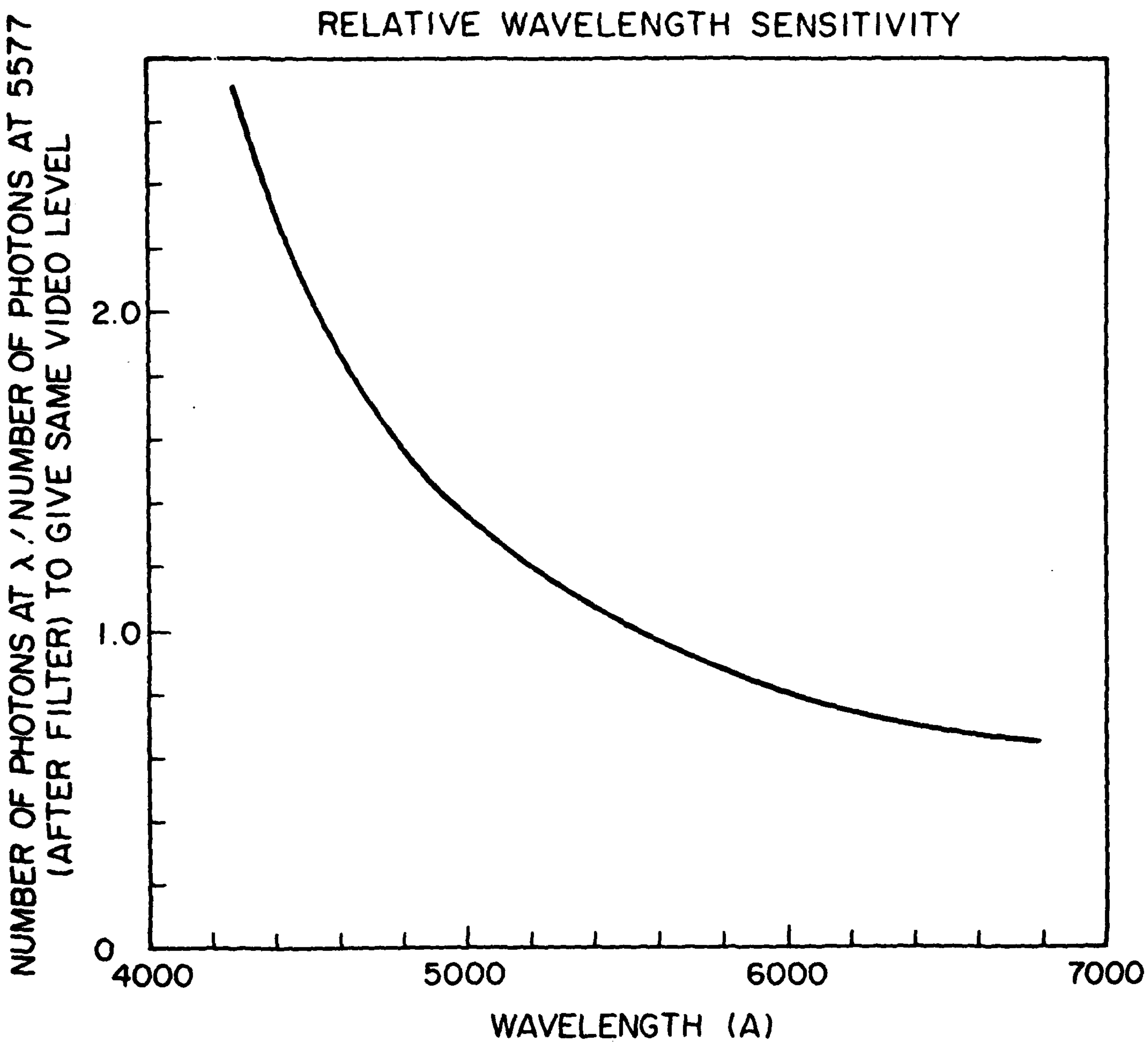

SATURATION
EXPOSURE TIME
120
60
30
15
8
4
2
USEFUL PIC-TURE
LIGHT SOURCE DR-2
HV = 940
VIDEO LEVEL (WFM)
60
40
20
0
0.01
0.1
1
10
INTENSITY (KR) 5577A
VIDEO VOLTS
0.5
0.4
0.3
0.2
0.1
0

FIGURE D3.



RELATIVE WAVELENGTH SENSITIVITY
NUMBER OF PHOTONS AT λ / NUMBER OF PHOTONS AT 5577
(AFTER FILTER) TO GIVE SAME VIDEO LEVEL
2.0
1.0
0
4000
5000
6000
7000
WAVELENGTH (A)

FIGURE D4.

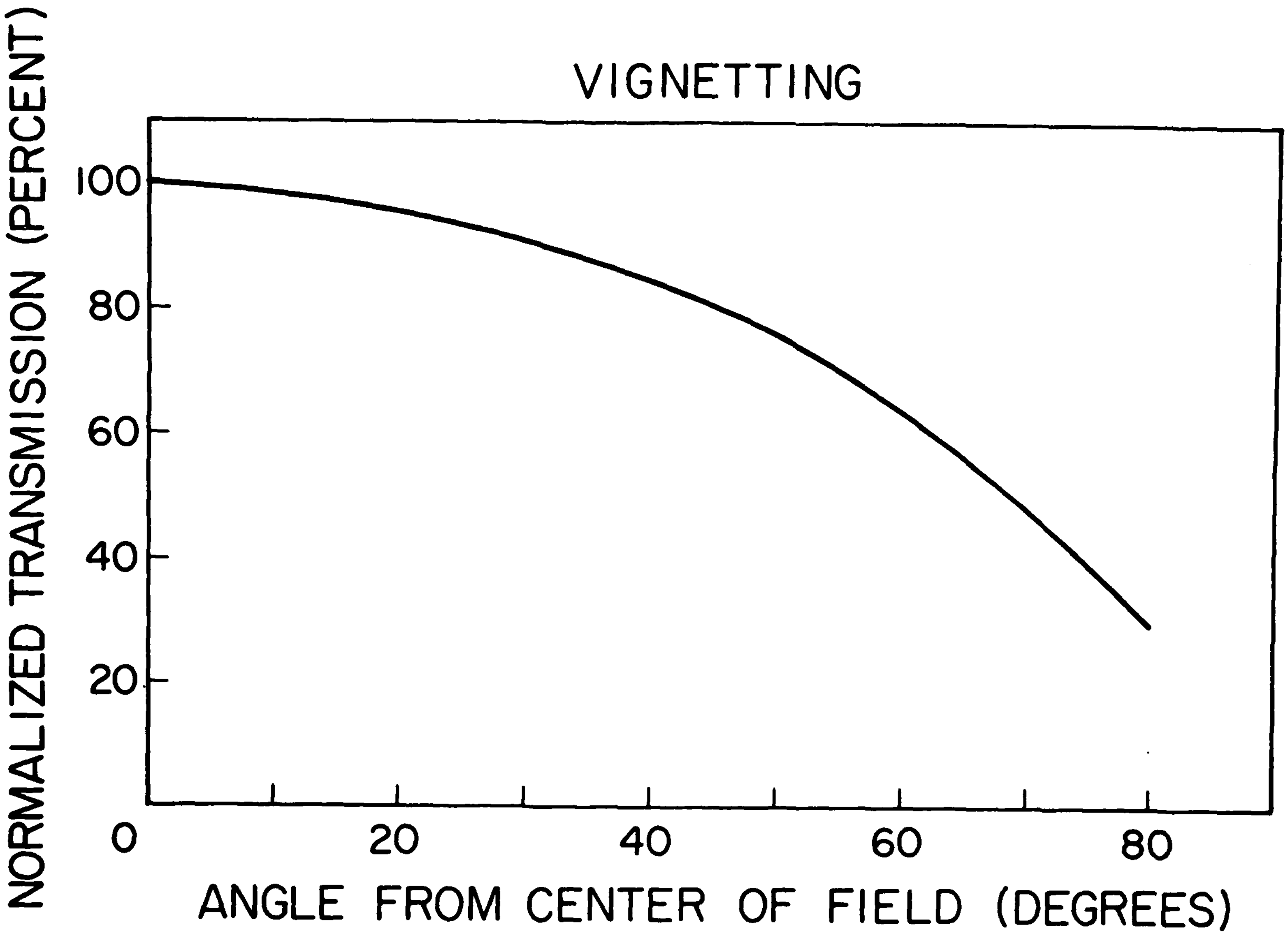

VIGNETTING
NORMALIZED TRANSMISSION (PERCENT)
100
80
60
40
20
0
20
40
60
80
ANGLE FROM CENTER OF FIELD (DEGREES)

FIGURE D5.

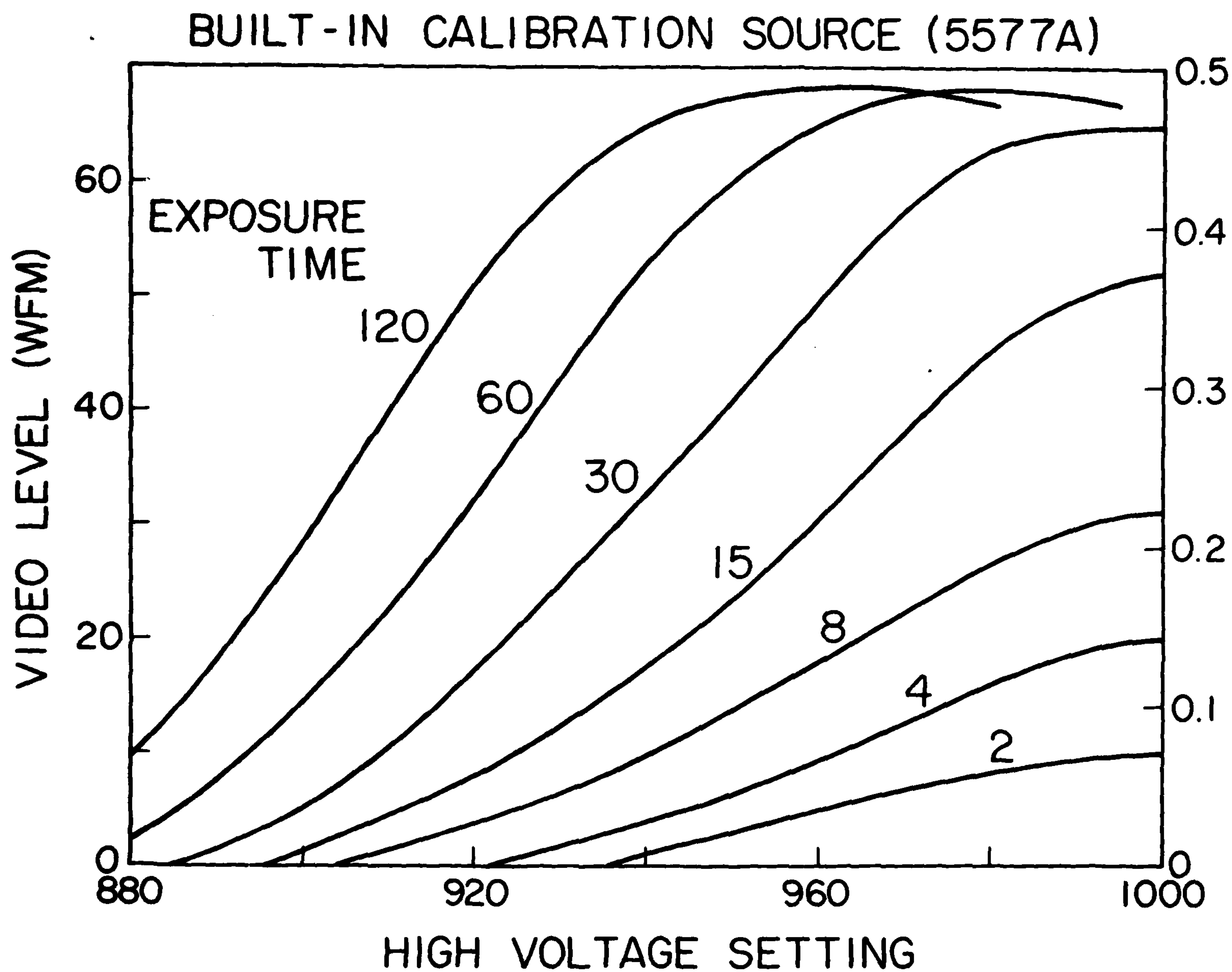

BUILT-IN CALIBRATION SOURCE (5577A)
EXPOSURE TIME
120
60
30
15
8
4
2
VIDEO LEVEL (WFM)
VIDEO VOLTS
HIGH VOLTAGE SETTING
0
20
40
60
880
920
960
1000
0.1
0.2
0.3
0.4
0.5

FIGURE D6.

DATE
ILMED

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